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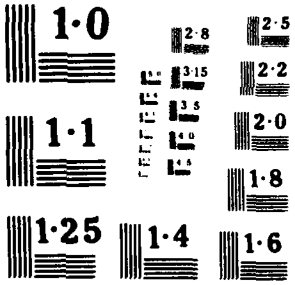
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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

AD-A151 438

FINGER MATERIALS FOR AIR CUSHION VEHICLES VOLUME I: FLEXIBLE COATINGS FOR FINGER MATERIALS

by

Paul K. Conn and Ivan Snell
Bell Aerospace Textron
and
William Klemens, DTNSRDC

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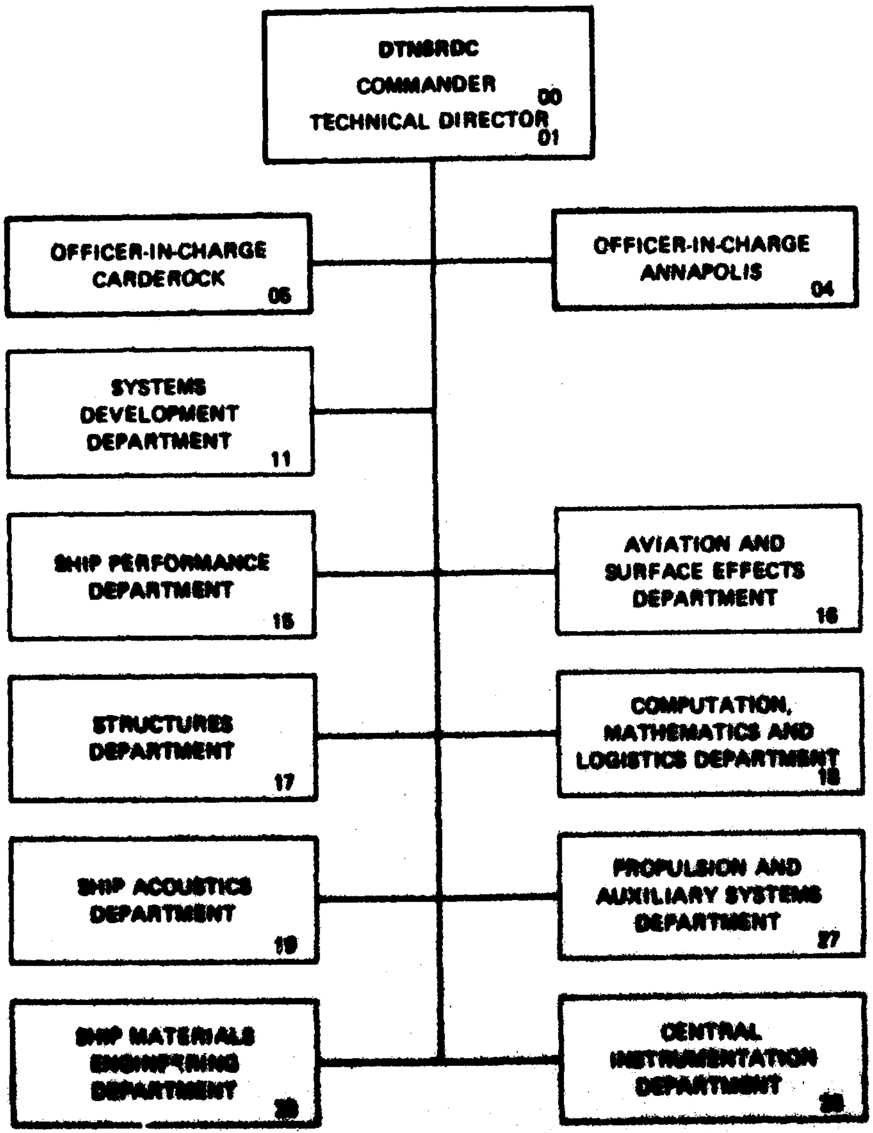
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2. GOVT ACCESSION NO. AD-A151438

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) [illegible]

5. TYPE OF REPORT & PERIOD COVERED
Final
[illegible]

6. PERFORMING ORG. REPORT NUMBER [illegible]

7. AUTHOR(s) [illegible]

8. CONTRACT OR GRANT NUMBER(s) [illegible]

9. PERFORMING ORGANIZATION NAME AND ADDRESS [illegible]

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Program Element [illegible]
Task Area SF [illegible]
Work Unit [illegible]

11. CONTROLLING OFFICE NAME AND ADDRESS
[illegible] Naval Ship R&D Center
[illegible]

12. REPORT DATE [illegible]

13. NUMBER OF PAGES [illegible]

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

[illegible] Rubber
Castable Liquid Polyurethanes
Rubber Coated Fabrics
Air Cushion Vehicle Flexible Materials
Skirt Seal Materials

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Twenty polymer formulations from ten selected gum rubber polymers or polymer blends and fourteen formulations of castable liquid polyurethane polymers were characterized as coatings for the coated fabric that is the type material used to make flexible fingers for air cushion vehicles. The formulations were screened for crack

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) [illegible] fatigue resistance of the coated [illegible] results from a coated fabric [illegible] advantage [illegible] of the better [illegible] surface [illegible] as tougher material [illegible], selected [illegible] characterization tests [illegible] results [illegible] was used to evaluate [illegible] improved [illegible]. Finally, [illegible] the polymer [illegible] were applied [illegible].

[illegible] better [illegible] resistance [illegible] better flexural fatigue resistance than [illegible]. A [illegible] polyether polymer [illegible] properties equivalent to the [illegible] nylon fabric. Hysteresis [illegible] different rates of deformation yielded results [illegible] the standard tests [illegible] not identify [illegible] performance of air cushion [illegible] coated woven fabric materials [illegible] lower tear strength at -[illegible] [illegible].

[illegible], knit, and mat structures were evaluated [illegible] for polymer coatings; the knit [illegible] were not as efficient on a strength- [illegible] woven fabrics. Castable polyure- [illegible] homogeneous material without [illegible] were found to exhibit poor [illegible] flexural fatigue resistance.

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TABLE OF CONTENTS

Page

LIST OF FIGURES iii

LIST OF TABLES v

ABBREVIATIONS AND ACRONYMS ix

ABSTRACT 1

ADMINISTRATIVE INFORMATION 2

ACKNOWLEDGMENTS 2

SUMMARY 2

INTRODUCTION 4

DETAILS OF EXPERIMENTAL WORK 5

PHASE I – RUBBER COATING DEVELOPMENT 6

PHASE II – HOMOGENEOUS MATERIALS DEVELOPMENT 25

PHASE III – FIBER MATERIALS DEVELOPMENT 30

CONCLUSIONS 33

APPENDIX A – SELECTION OF GUM RUBBER POLYMERS 37

APPENDIX B – CASTABLE POLYURETHANE POLYMERS 67

APPENDIX C – SCREENING AND CHARACTERIZATION TESTS 73

APPENDIX D – DETAILED EXPERIMENTAL DATA 77

APPENDIX E – THE THERMAL CONDUCTIVITY OF THREE
ELASTOMERS 111

APPENDIX F – LIST OF SUPPLIERS 113

LIST OF FIGURES

[illegible] – Tear Strength Versus Temperature 24

6.1 Penetration of Formulation #205 Polyurethane
Into Polyester Mats of Weight 5.5, 11.8,
and 14.[illegible] Ounces per Square Yard 69

Page

[illegible] . . . . [illegible]

[illegible] per Minute [illegible] . . . . [illegible]

[illegible] per Minute [illegible] . . . . [illegible]

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[illegible] Absorption Versus Time for [illegible] Coated Nylon Fabric . . . . [illegible]

[illegible] Water [illegible] and Absorption Versus Time for [illegible] Coated Nylon Fabric . . . . [illegible]

LIST OF TABLES

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ABBREVIATIONS AND ACRONYMS

ACV	Air Cushion Vehicle
ASTM	American Society for Testing and Materials
BAT	Bell Aerospace Textron
[illegible]	[illegible]
°C	Degrees Celsius
cps	Cycles per second
cpm	Cycles per minute
cc	Cubic centimeters
[illegible]	[illegible]
DTNSRDC	David Taylor Naval Ship Research and Development Center
[illegible]	[illegible] Branch
EPDM	Ethylene propylene diene terpolymer
°F	Degrees Fahrenheit
[illegible]	[illegible] Development Laboratory
FEF	Fast Extrusion Furnace Carbon Black
g/cc	Grams per cubic centimeter
[illegible]	[illegible]
HAF	High Abrasion Furnace Carbon Black
HMDI	Dicyclohexylmethane diisocyanate
hr	Hour
Hz	Hertz
[illegible]	[illegible]
IPDI	Isophorone diisocyanate
ISAF	Intermediate Super Abrasion Furnace Carbon Black Low Structure
	Jet Propulsion Fuel No. 5
K	Degrees Kelvin
kg	Kilogram
LACV-30	Lighter Air Cushion Vehicle - 30 ton payload
[illegible]	Pounds per [illegible]
LSES	Large Surface Effect Ship
MBT	Mercaptobenzothiazole
MBTS	Benzothiazyl disulfide
MDA	Methylene Dianiline
MDI	Diphenylmethane diisocyanate

of propylene oxide polymer and was ineffective with the chlorinated polyethylene polymer. This is contrary to published results for a natural rubber/SBR butadiene blend.* The concentration used may not have been best for the particular polymers.

The crack growth and flexural fatigue results for the castable liquid polyurethanes are summarized in Table [illegible]. These formulations were prepared by reacting high molecular weight hydroxy terminated polyethers, polycarbonates or polybutadienes with [illegible] two diisocyanates partially; the prepolymers resulting from these reactions were [illegible] subsequently with either a low molecular weight hydroxy terminated hydrocarbon or a diamine as discussed in Appendix B. In several instances, a reactive silicone also was added to the polymer. These particular formulations had suitable [illegible] kinetics for casting, and crack growth and flexural fatigue specimens were [illegible] the appropriate mold immediately after mixing and degassing the liquid. The formulations were cured at room temperature for several days prior to testing; [illegible] formulations were post cured at [illegible]°C ([illegible]°F) for [illegible] following room temperature cure.

The results in Table [illegible] show that [illegible] of the [illegible] formulations had better crack growth resistance than the standard BAT-1[illegible], and five (PU-19[illegible], PU-19[illegible], PU-19[illegible], [illegible]) of these were substantially better. In contrast, only one of [illegible] (PU-19[illegible]) had better flexural fatigue resistance, and two (PU-[illegible]) had approximately the same flexural fatigue resistance as the standard.

Based on the preliminary screening tests, six rubber formulations BAT-[illegible], BAT-[illegible], BAT-[illegible], BAT-41[illegible], BAT-41[illegible], and BAT-41[illegible], and castable liquid polyurethanes [illegible], PU-19[illegible], PU-19[illegible], PU-198, and PU-[illegible] were selected for characterization [illegible] primary and secondary characterization tests listed in Appendix C.

Results from the primary characterization tests of the polymer formulations are [illegible] the next four tables. In Table 3 are summarized the hardness, tensile properties, tear properties, pico abrasion index, and coating adhesion. Values for the [illegible] property hysteresis, as measured on the Goodrich flexometer, are [illegible] Table 4. Resilience is summarized in Table [illegible] for the Lupke rebound [illegible] Table 6 for the Yerzley method. In these tables, the results for [illegible] polymers are compared to results for the control formulation, ECB-502.

---

*[illegible], G.G., Loban, R.D., "Effects of Molybdenum Disulfide on Elastomer Flex Life and Other Properties," paper presented at a meeting of the Rubber Division, American Chemical Society, New Orleans, LA (7-10 Oct 1975).

Generally, the variables in the formulations were the type and amount of carbon black, the substitution of some silica for carbon black, the type and amount of [illegible], the type of [illegible] antioxidant, the use of polymer blends, and the type of cure system. One [illegible] (BAT-[illegible]) and one [illegible] (BAT-[illegible]) formulations were [illegible] intentionally to investigate the effects of [illegible]. [illegible] chlorinated polyethylene (BAT-[illegible]) [illegible] flexural fatigue life.

[illegible] specimens. [illegible] flexural fatigue [illegible] flexural fatigue life of the [illegible].

[illegible] BAT-[illegible] polyethylene [illegible] formulation [illegible] control rubber formulation. [illegible] natural ethylene propylene blend) BAT-[illegible], BAT-[illegible] (SB block copolymer (SBR blend)), BAT-[illegible] natural blend), BAT-[illegible], BAT-[illegible] and [illegible] chlorinated [illegible] (BAT-[illegible]) (phosphonitrilic fluoroelastomer). Two polymer types, [illegible] rubber, did not yield formulations which were as good as [illegible] properties.

The results show that the crack growth and the flexural fatigue resistance were [illegible] both Batch 2 and Br-[illegible] polymers. However, the use of [illegible] disulfide was detrimental to the crack growth and flexural fatigue life

[illegible] evaluated, and the constituents used for castable [illegible] appendices along with a listing of the charac[illegible] [illegible] experimental data, and a description of the thermal [illegible].

[illegible]

[illegible] formulations of [illegible] selected [illegible] resistance to crack initiation [illegible] selection [illegible] the formulations [illegible] test results, [illegible] with the [illegible] Appendix [illegible]. [illegible] Appendix [illegible]. [illegible] the [illegible] subject. The coated fabric [illegible] Aerospace Tests [illegible] with the exception of the [illegible].

[illegible] were prepared [illegible] These formulations were [illegible] four formulations were selected for [illegible] tests. Finally, two [illegible] of rubber coated fabric which were [illegible] tests.

[illegible] resistance results for [illegible] rubber [illegible] Table [illegible]. A more detailed listing of the experimental results [illegible] presented in Appendix [illegible]. The formulations were developed and prepared by [illegible] with the assistance of customer service [illegible] were cured at the recommended cure conditions in appropriate molds. The control formulation [illegible] was mixed by a commercial company; the cure was based on the rheometer data obtained on the mix.

RESULTS OF EXPERIMENTAL WORK

Fingers on air cushion vehicles are subjected to very high frequencies of vibration for example, 200 cps at relatively large amplitudes. When rubber coated fabrics are subjected to cyclic stresses through repeated or intermittent flexing, the development of cracks in the coating and delamination from the fabric become frequent causes of failure. During rapid flexing, the ability to sustain rapid strain rates and rapid strain recovery rates without crack formation is important. At high rates of flexing, heat build-up may occur so that high temperature (60-150°C) (140-302°F) properties may be important.

Desirable properties of polymer coatings have been inferred from current knowledge of the seal motions and observed damage. The polymer coating should have high flexural, compressive, and tensile fatigue resistance; high flex crack and crack growth resistance; low flexural modulus; high impact resistance; high abrasion resistance; high tear strength; low hysteresis or excellent high temperature properties; high bond strength to itself and to nylon fabric reinforcement; and excellent environmental resistance (water, sunlight, ozone, fuel).

The principal criteria for evaluation of the polymers were comparisons of measured properties to the measured properties of known materials which had service evaluation. In the case of gum rubber polymers, the known material was a natural/neoprene rubber blend formulation which was developed by Bell Aerospace Textron on another program and designated FCB-[illegible]. This formulation was coated on woven nylon fabric and used successfully as bow and side fingers on the British SR.N4 cross channel ferry and on the Army LACV-30 amphibious air cushion vehicle. Among castable liquid elastomers, the known material was a polyurethane formulation developed by Bell Aerospace Textron and designated BAT-[illegible]. This formulation was coated on woven nylon fabric and used successfully as side fingers on an Army LACV-30. The woven nylon fabric used with the two different rubber coatings for the LACV-30 fingers had the same weight and configuration, and was designated fabric 178b.* This fabric is a [illegible] basket weave of [illegible] oz yd² and was also used as the fabric in this program.

The work is reported under three tasks and five appendices. The experimental results are summarized and discussed in this section. The rationale for polymer

---

*Woven by Fabric Development Laboratory, Quakertown, PA.

INTRODUCTION

Surface effect ships and air cushion vehicles require a flexible seal or skirt structure to contain the cushion of air on which the craft is supported. The flexibility is necessary to minimize contact (reduce drag) between the vehicle structure and the surface being traversed, which is normally various types of ground terrain or water.

The flexible seals of these craft have typically been fabricated from rubber coated woven fabric laminate materials which were developed originally for applications such as conveyor belts and liquid storage containers. The air cushion craft are exposed to dynamic environments that are more demanding than those for the original applications. These more demanding requirements result from increased mechanical loads, from increased rate of load application, and from environmental extremes which may lead to intolerable or undesirable chemical and physical changes. Hence, substantial improvements of these flexible materials are required to provide adequate structural performance and long operational life with minimum weight and maintenance.

The objective of this program was to develop optimum rubber coatings for flexible seal skirt applications for surface effect ships and vehicles. The primary emphasis was on gum rubber formulations based on selected synthetic rubber polymers and castable liquid polyurethane polymers for use as woven fabric coatings. The program included a thermally conductive formulation, formulations for use without reinforcement (homogeneous materials), reinforcements other than woven fabrics, and evaluation of rubber coated fabrics.

Rubber formulations were initially evaluated alone, and then as coatings on nylon fabric. The evaluations were performed by using standard ASTM tests for selected mechanical properties. Since no correlation had been established between standard mechanical properties and service life on a vehicle, the evaluations were accomplished by comparing results from the experimental materials to results obtained from an existing natural/butadiene rubber blend coated nylon fabric which had been used successfully on an Army LACV-30 air cushion vehicle. Test pieces and sample materials were fabricated for evaluation by Bell Aerospace Textron and the DTNSRDC Annapolis Laboratory.

FOREWORD

The high speed and versatility of Air Cushion Vehicles (ACV) offer significant potential for military applications. However, in amphibious transit over land and water, the lower appendages, called fingers, are subjected to severe flexing and erosion, shortening the life of the finger. As a result, craft performance is degraded and life cycle costs increase. The objective of this exploratory development project was to develop sufficient information on fabric and coatings to guide development or selection of coated fabrics as finger materials for Navy air cushion craft.

This volume, the first of three, describes a comprehensive evaluation of elastomeric finger materials for air cushion vehicles. The approach taken, in which materials were screened in preliminary dynamic tests in order to identify candidates for further research, was a sensible and economic approach. Basically, in this work, the fabric was held constant and the coating was varied. Volume II [illegible] publication describes the effect from fabric structure on the performance of finger materials. Here, the coating was held constant and the fabric was varied. A natural rubber polybutadiene blend coating was common to both endeavors and served as a reference control tying both efforts together. Volume III (to be published) describes the coated fabric as a finger material. Performance was evaluated on the [illegible] dynamic testing facility called the "Drum Tester" and on the fleet of operational air cushion vehicles. The information [illegible] was used to define coated fabric constructions which were subsequently fabricated and tested as detailed in the third volume.

Further evaluation performed after completion of the work reported here has focused on natural rubber polybutadiene blend formulations. This is because these coatings [illegible] offer the greatest resistance to fatigue. Although, this report contains results which indicate that natural rubber polybutadiene blend formulations do not necessarily offer the greatest resistance to fatigue. No correlation has been found between those results reported here and the subsequent testing.

ADMINISTRATIVE INFORMATION

[illegible] the Surface Effect Ship [illegible] Materials [illegible] Lederfeld III, Naval [illegible] Mr. [illegible] Halliwell, [illegible], under [illegible]. This report satisfies [illegible].

ACKNOWLEDGMENTS

[illegible] for their assistance [illegible].

[illegible] have made significant contributions. [illegible], we [illegible] Mr. Alfred Watt and Mr. George Pappelt for their support. [illegible], Mr. [illegible] and Mr. [illegible] Powers directed the laboratory work on [illegible] characterization, and Mr. Edward Jones assisted in this work. [illegible], advised on the castable liquid [illegible].

[illegible] Surface Effect Materials program, [illegible] Air Cushion Program Office [illegible] field tested experimental [illegible] Experimental Trials Unit [illegible] for trials on the SES-100B; the U.S. Army [illegible] Fort Belvoir, Virginia, [illegible]; the Canadian [illegible]; and Hoverspeed, Ltd. in Dover, Kent, [illegible]. A special note of thanks goes to Mr. [illegible], Office of Naval [illegible], Washington, D.C., Dr. H.H. Vanderveldt of the Naval Sea Systems Command, Washington, D.C., and Dr. W. Denney Freeston of the Georgia Institute of Technology, Atlanta, Georgia, for their foresight and guidance throughout this project.

ABSTRACT

Twenty polymer formulations from ten selected gum rubber polymers or polymer blends and fourteen formulations of castable liquid polyurethane polymers were characterized as coatings for the coated fabric that is the tape material used to make flexible fingers for air cushion vehicles. The formulations were screened for crack growth and flexural fatigue resistance; the results were compared to results from a natural rubber [illegible]

In addition, selected polymers were evaluated with primary and secondary characterization tests and the results compared to results from the control formulation. [illegible] polymer also was used to evaluate the use of a reticulated carbon black to improve thermal conductivity. Finally, five of the polymer formulations and the control [illegible] were applied to nylon fabric and evaluated.

Several polymers had better crack growth resistance and [illegible] polymer had better flexural fatigue resistance than the control polymer. A chlorinated polyethylene polymer coated on nylon fabric had properties equivalent to the control polymer coated on nylon fabric. Hysteresis tests at different rates of deformation yielded results which suggested that the standard tests may not identify polymers with improved performance on air cushion vehicles. Two polymer-coated woven fabric materials exhibited significantly lower tear strength at -[illegible] C ([illegible] F) than at [illegible] °C.

Woven fabric, knit, and mat structures were evaluated as reinforcements for polymer coatings; the knit and mat structures were not as efficient on a strength-to-weight basis as woven fabrics. Castable polyurethanes were evaluated as a homogeneous material without a fiber reinforcement and were found to exhibit poor crack growth and flexural fatigue resistance.

Resilience results on the polymers (Yerzley method) are given in Table 6. In this test, an initial [illegible] compressive deformation is applied to the specimens; upon release, the specimen begins a train of cycles, which decays due to hysteresis. The results suggest that, in partial agreement with the Lupke results, one chlorinated polyethylene (BAI-[illegible]), is similar to the control formulation ECB-[illegible]; the similarity exists in resilience (energy recovered) but not in the speed of rebound, for which BAI-[illegible] exhibited a greater speed of recovery. The remaining gum rubber polymers exhibited less resilience than the control with recovery times both faster and slower than the control speed. Two of the polyurethanes (PU-183 and -205) exhibited excellent resilience and rates of recovery all greater than the control; the remaining two polyurethanes (PU-185 and -198) straddled the control both in resilience and rate of recovery, although the polymer with the higher resilience had the lower rate of recovery.

In all three of these dynamic tests, polymer deformation is compressive: the Goodrich Flexometer is forced high cyclic rate compression-compression, Lupke rebound is a single cycle compression, and the Yerzley rebound is a multiple cycle compressive deformation with the cyclic rate and number of cycles controlled by the viscoelastic properties of the polymer. Since polymer coatings on the seals of air cushion vehicles are subjected to high cyclic rate and concurrent large displacement tension-tension, tension-compression, and compression-compression cyclic stresses, results from the Goodrich Flexometer test may be the most important of the three tests. High cyclic rate, large displacement tension-tension fatigue tests also should have been done but these tests were beyond the scope of the program.

Thermal conductivity of three formulations was measured at each of two different temperatures to evaluate the use of a reticulated carbon black to increase the thermal conductivity of polymer formulations. The three formulations were styrene-ethylene butylene-styrene block copolymer (SEBS) with 2 parts per hundred parts rubber (pphr) antioxidant [illegible], and 2 pphr Tinuvin [illegible]; the same block copolymer formulation with [illegible] pphr Ketjenblack EC; and the control formulation ECB-[illegible].

The thermal conductivity results are presented in Table 7.

[illegible] location. Materials which [illegible] to determine [illegible].

TABLE 10 – OZONE AND OUTDOOR WEATHERING RESISTANCE OF POLYMER FORMULATIONS

[illegible]	Polymer	Type of Damage Observed	Time of Damage Days
BAT-[illegible]*	Carboxylated Nitrile	Shallow, widely spaced cracks, [illegible]	[illegible]
BAT-[illegible]*	[illegible] EPDM Natural Rubber Blend	None	[illegible]**
BAT-[illegible]*	Propylene Oxide	Cracks [illegible]	[illegible]
BAT-[illegible]*	[illegible] Natural Rubber Blend	[illegible] cracks	[illegible]
BAT-[illegible]*	[illegible]	Cracks, probably [illegible]	[illegible]
BAT-[illegible]*	[illegible]	No cracks	[illegible]**
[illegible]*	Natural Rubber-[illegible] Blend	[illegible] cracks Extensive [illegible]	[illegible]
[illegible]***	[illegible]	Cracking Small cracks	[illegible]
[illegible]***	[illegible]	Cracking	[illegible]
[illegible]***	[illegible]	Cracking Small cracks	[illegible]
[illegible]***	[illegible]	Cracking Cracking	[illegible]

* [illegible]

** [illegible]

*** [illegible]

The natural rubber-butadiene blend control [illegible] tensile strength and elongation after [illegible], [illegible] the [illegible] polymer/natural rubber [illegible], BAT-[illegible], [illegible] BAT-[illegible], the propylene oxide BAT-[illegible], [illegible] exhibited serious [illegible]. [illegible] were [illegible] polymers and are consistent with [illegible] swelling which was [illegible]. At the same time, little [illegible] carboxylated nitrile BAT-[illegible] polyurethane BAT-[illegible], [illegible] control [illegible]. [illegible] polymers are [illegible]; [illegible] exhibits surprisingly good resistance [illegible] fuel when compared to the results for the other three polyurethane formulations.

The ozone and outdoor weathering resistance of the natural rubber-butadiene blend polymer was poor (Table 10), and all the other polymers and polymer blends exhibited better resistance than did the control. The propylene oxide BAT-311, the [illegible] BAP [illegible] and the [illegible]

[illegible] results [illegible] BAP [illegible] Flexometer [illegible] polymers were not [illegible] were similar to control polymers, they were all [illegible] comparison with the control polymer. [illegible] Table 10, [illegible] other polymer formulation [illegible] BAP [illegible] in the testing.

[illegible] polymer [illegible] BAP [illegible]

[illegible] were not included [illegible] because [illegible] polymer [illegible]

[illegible]

[illegible] were used [illegible]

[illegible] were reconnected [illegible]

[illegible] of the fabric [illegible] each side of the [illegible] the coating penetrated the [illegible] the first. After [illegible] and [illegible] were post cured for [illegible]

[illegible]

[illegible]	Fabric Test Direction	Test Temperature °C (°F)	Ultimate Tensile Strength pli	Ultimate Elongation %	Tear Strength lb	Coating** Adhesion lbs/in.
[illegible]	Warp	49 (120)	1060	38	550	-
		24 (75)	1090	43	[illegible]20***	
		1 (30)	960	38	39	-
	Fill	49 (120)	84[illegible]	26	55	
		24 (75)	800	22	500	
		1 (30)	86[illegible]	19	19[illegible]	
[illegible]	Warp	49 (120)	1050	47	[illegible]*	-
		24 (75)	1090	29	[illegible]	
		1 (30)	90[illegible]	32	[illegible]	
	Fill	49 (120)	[illegible]3	26	[illegible]	
		24 (75)	[illegible]	17	[illegible]	
		1 (30)	10[illegible]	25	11[illegible]	
[illegible]	Warp	49 (1[illegible])	1[illegible]8	[illegible]	[illegible]	
		24 ([illegible])	1[illegible]5	[illegible]	[illegible]*	
		[illegible]	11[illegible]	[illegible]	5[illegible]*	
	[illegible]	49 ([illegible])	1[illegible]8	[illegible]	[illegible]*	
		24 ([illegible])	1[illegible]6	26	5[illegible]*	
		1 ([illegible])	11[illegible]	[illegible]	56*	
[illegible]	[illegible]	49 ([illegible])	Rubber coverage sheared from fabric††			
		24 ([illegible])	11[illegible]	[illegible]	550*	
		[illegible]	Test not performed		[illegible]***	
	[illegible]	[illegible]	11[illegible]	29	**	
		[illegible]	12[illegible]	[illegible]	63	
		[illegible]	Test not performed		48 ***	
[illegible]	Warp	49 ([illegible])	1[illegible]	[illegible]	-	
		24 ([illegible])	117	[illegible]	[illegible]	[illegible]
	Fill	49 ([illegible])	96[illegible]	25	[illegible]*	
		24 ([illegible])	110[illegible]	[illegible]	[illegible]*	
[illegible]	Warp	49 (12[illegible])	1080	47		
		24 ([illegible])	11[illegible]	4[illegible]	[illegible]*	
	Fill	49 ([illegible])	[illegible]	29		
		24 (75)	112[illegible]	[illegible]	11[illegible]*	

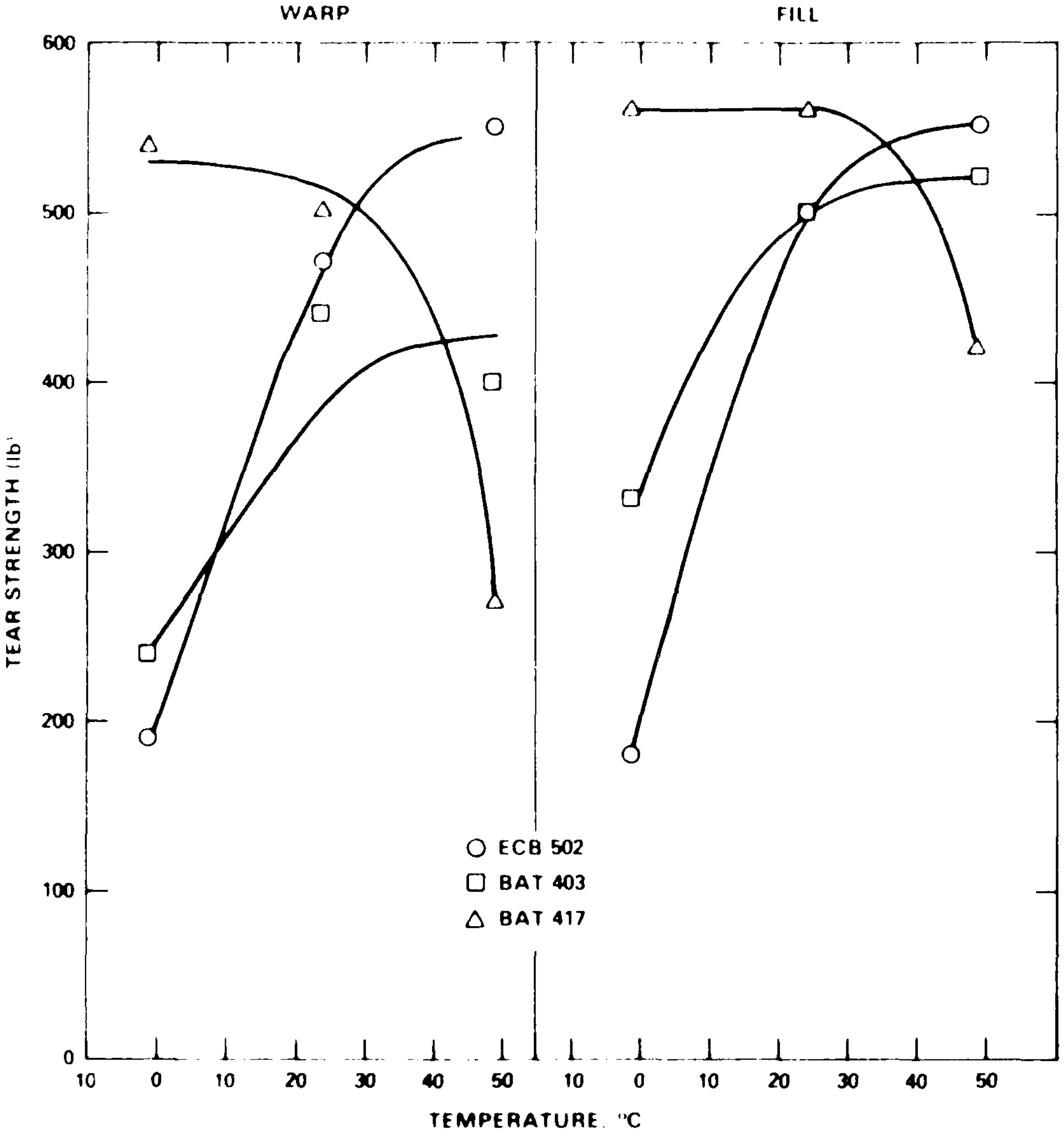
*The nylon woven fabric was a 3 x 3 basket weave of 21 oz/yd² obtained from Fabric Development Laboratories, Quakertown, PA, with their designation 1[illegible]85.

**Tie coat [illegible] was used to bond the gum rubber polymers to the fabric and Silane [illegible] was used as an adhesion promoter with the polyurethane polymers.

***Nylon cord partially pulled through the rubber and partially broke.

†Nylon cord pulled through the rubber and did not break.

††The Neoprene rubber tie coat retarded the cure of the chlorinated polyethylene at the interface so that the chlorinated polyethylene remained a thermoplastic at the interface which softens markedly between 43° (109°F) and 49°C (120°F).


WARP
FILL
600
500
400
300
200
100
0
TEAR STRENGTH (lb)
10
0
10
20
30
40
50
10
0
10
20
30
40
50
TEMPERATURE, °C
○ ECB 502
□ BAT 403
△ BAT 417

[illegible] for application [illegible]

[illegible]

[illegible] heat buildup [illegible] are generated [illegible] dissipated [illegible] must [illegible], energy dissipation [illegible]. [illegible] the number of persistent [illegible] network and between network and filler surface. It may be [illegible] energy dissipation [illegible] at the maximum since one [illegible] other. Consequently, compounding variations can have quite complex effects on [illegible] crack development and propagation. Generally, compounding

[illegible]

[illegible]

[illegible]	Parts By Weight
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Weight Percent	
[illegible]	10
[illegible]	[illegible]
Trichloroethylene	[illegible]

Add a trifunctional polyisocyanate
(PAPI) just before use.
Heat set 2-6 min at 177 °C (350 °F)

[illegible] CONTENT OF CONTROL FORMULATION FCB-[illegible]

Ingredients	Parts by Weight
[illegible] Rubber [illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

APPENDIX A

SELECTION OF GUM RUBBER POLYMERS

[illegible] WORK

[illegible] rubber polymer formulation development for [illegible] coatings on woven fabric [illegible] was based on [illegible] polymer or polymer blends. [illegible] polymer blends were formulated with [illegible] polymers. [illegible] formulated with one half of the polymer [illegible] environmental properties. The polymers, [illegible] presented in Table A-1. [illegible] was investigated with [illegible].

[illegible] formulations were screened and compared to a [illegible] blend polymer which was a government-furnished reference [illegible]. The contents of this formulation are shown [illegible] different antiozonant and anti- [illegible] better materials evaluated to date for fingers on the [illegible] air cushion vehicle. The formulation [illegible] Aerojet [illegible] for the Large Surface Effect Ship Program.

[illegible] were evaluated with initial screening tests and [illegible] results [illegible] natural rubber butadiene polymer blend [illegible]. The six best formulations were selected and evaluated further with [illegible] tests (Appendix C) and the results compared [illegible] results obtained from the control polymer formulation. The three best formulations were selected, and together with the control formulation, used as [illegible]. The coated fabrics were characterized with property [illegible] (Appendix C).

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[illegible]. Polymers reinforced with knit and mat structures do not exhibit as good [illegible] tear strength as polymers reinforced with woven fabric for the same [illegible] reinforcement.

[illegible]. A [illegible] liquid polyurethane was developed which had relatively good [illegible], and outdoor weathering, but the flexural fatigue and [illegible] were relatively poor.

[illegible] polymers formed from polybutadiene/styrene [illegible] al instability under very high [illegible] compressive [illegible] temperature rise caused by hysteresis in the [illegible].

[illegible] castable liquid, elastomeric [illegible] feasible method for the fabrication of sheets of [illegible] (see Appendix B).

[illegible] nitrile, the [illegible] EPDM natural rubber blend, and the [illegible] polybutadiene styrene copolymer [illegible] equivalent to the natural butadiene blend control [illegible] exhibited outstanding resistance to fuel. [illegible] liquid polyurethane [illegible] exhibited good resistance to fuel.

[illegible] weathering resistance [illegible] exhibited poor resistance), [illegible] polyethylene, and [illegible] resistance [illegible] rubber and [illegible].

[illegible] coated woven fabric [illegible] water wicking [illegible], whereas the rubber coated woven fabric [illegible] water wicking [illegible] weight [illegible].

[illegible] evaluation [illegible] suggesting that these tests may be of little value in [illegible] improved performance [illegible].

[illegible] evaluation of polymer coated woven fabric [illegible] natural rubber blend, [illegible] polyethylene polymer coated fabric [illegible] fabric samples coated with the natural [illegible]. The castable liquid polyurethane [illegible] the [illegible].

[illegible] fatigue evaluation of polymer coated woven fabric [illegible] displacement conditions indicated that the [illegible] fabric coated with chlorinated polyethylene [illegible] resistance and were somewhat more resistant than fabric coated [illegible] natural rubber blend or fabric coated with [illegible] rubber blend; the results also showed that the coated fabric [illegible] in the warp direction than in the fill direction [illegible] which were used.

[illegible] Homogeneous materials based on castable liquid polyurethane polymers could [illegible] developed with properties equivalent to polymer coated woven fabric; polymer coated woven fabric exhibited [illegible] superior flexural fatigue and crack growth resistance, flexibility, and tear resistance.

CONCLUSIONS

1. Results from laboratory tests at 5 cps on [illegible] rubber formulations prepared from [illegible] synthetic polymer or polymer blend systems indicated that: a) two of the formulated polymer systems (carboxylated nitrile and chlorinated polyethylene) had crack growth resistance greater than that of the control polymer blend (natural rubber/butadiene); and b) six of the formulated polymer systems (carboxylated nitrile, bromobutyl/natural rubber/EPDM blend, SB block copolymer/SBR blend, SB block copolymer/natural blend, chlorinated polyethylene, phosphonitrilic fluoroelastomer) had flexural fatigue resistance greater than that of the control polymer blend.

2. Results from laboratory tests at [illegible] cps on a variety of liquid castable polyurethane polymer formulations prepared from five different polyalcohols, four different diisocyanates, and four diamine or dialcohol curatives indicated that: a) eleven liquid polyurethane formulations had better crack growth resistance than the control polyurethane polymer (BAI-1[illegible]); and b) one formulation had better flexural fatigue resistance than the control and one formulation had about the same flexural fatigue resistance as the control.

3. Nylon woven fabric coated with the natural rubber/butadiene blend control polymer exhibits a marked reduction in tear strength at [illegible] compared to tear strength at room temperature. Similar effects, but to lesser degrees, are exhibited by the bromobutyl/EPDM/natural rubber blend coated woven fabric at [illegible] and the SB block copolymer/natural rubber blend coated woven fabric at [illegible]. The reduction in strength appears to be caused by a modulus change of the polymer such that the polymer causes the fibers in the yarn bundles to fail prematurely. Consequently, for complete characterization, polymer coated woven fabrics should be evaluated for mechanical properties over the range of temperatures anticipated for air cushion vehicle use.

4. Ketjenblack EC conductive carbon black appears to more effectively increase the thermal conductivity of polymers than regular reinforcing carbon blacks. Since Ketjenblack EC is non-reinforcing in most polymers, a detailed study is necessary in [illegible] with reinforcing carbon blacks to determine if optimum mechanical and [illegible] properties can be obtained concurrently with improved thermal conductivity.

5. Based on the Pico laboratory abrasion test, the SB block copolymer/natural rubber polymer blend had superior abrasion resistance compared to the natural rubber/butadiene blend control polymer, and one castable liquid polyurethane polymer exhibited better abrasion resistance than the control.

[illegible], style [illegible], are presented in Table 17. The materials are prepared by [illegible] knitting, which features a lock stitch that prevents raveling. The poly[illegible] was selected for use in this program since it possesses strength approaching [illegible] both warp and fill directions but at a fabric weight of only 14.7 [illegible] of nylon. The manufacturer advised that the [illegible] polyester is as good as, or better than, that of the [illegible].

[illegible] polyester knit material were coated with formulation [illegible] of the nonreinforced formulation [illegible] also was cast. [illegible] material that the unexpected cure properties of [illegible] the oven cured and followed by postcure [illegible] lower tensile strength than [illegible] during [illegible], Appendix B.

TABLE 17. PROPERTIES OF NYLON AND POLYESTER KNITS

[illegible] No.	Material	Denier	Weight oz/yd²	Tensile Strength pli		Ball Burst lb
				Warp	Fill	
[illegible]	Nylon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Polyester	[illegible]	14.7	609	352	500

The polyester knit reinforced PU [illegible] polymer was tested at three temperatures. [illegible] tensile strength, tear strength and coating adhesion results are presented [illegible] Table 18, and [illegible] fatigue results are presented in Table 19. Since the rein[illegible] the tensile and tear strength of reinforced polymers, the [illegible] compared to the results obtained on woven fabric reinforced PU [illegible] Table [illegible]. A comparison of the results shows that the knit reinforced PU [illegible] has [illegible] the tear strength of the woven fabric reinforced [illegible] approximately the same reinforcement weight. However, the [illegible] is approximately three times greater than the woven fabric reinforced material. While the coating adhesion value for the knit material appears [illegible], [illegible] of the polyester knit [illegible] large areas of strike [illegible] that the test in this case is measuring cohesive strength of the [illegible] rather than the force required to peel the elastomer from the knit. A knit reinforcement structure does not yield as efficient a reinforcement as a woven fabric on a strength-to-weight basis.

[illegible] PARAMETERS AND [illegible]
[illegible]

[illegible] PARAMETERS

Tullanox [illegible]
Silica

[illegible]

[illegible]

[illegible] flexing resistance and excellent [illegible] as well as excellent [illegible] low temperature [illegible] properties including resilience and hysteresis [illegible] of natural rubber and much improved resistance to high temperature. Experiments [illegible] rubber formulations conducted in connection with the [illegible]* indicated that good peel adhesion to nylon could be obtained using neoprene rubber is [illegible] the coat, the peel adhesion values were in ex[illegible] of [illegible] for the two formulations evaluated. The polymer has only fair to good heat resistance and [illegible] fair resistance to oils. Blends with neoprene have been [illegible] the heat resistance and perhaps blends with nitrile or [illegible] oil resistance without sacrificing other properties.

---

*Mr. Paul [illegible], MERADCOM, Fort Belvoir, VA.

[illegible] rubber has excellent resistance to hydrocarbon fuels and oils, [illegible] resistance to ozone and oxidation, [illegible] itself. The polymer is rated only fair in [illegible]. Nevertheless, most of the [illegible] were fabricated [illegible] neoprene [illegible].

[illegible] rubber. [illegible] polymer [illegible] with other polymers [illegible] natural, [illegible] nitrile, [illegible] properties. [illegible]

[illegible] polymer [illegible] good [illegible] resistance [illegible] growth. It has excellent [illegible] rated very good for heat [illegible] resistance. Blending the polymer with [illegible] the heat resistance and resistance to [illegible] excellent flame resistance.

[illegible] styrene-butadiene-styrene (SBS) are thermoplastic rubbers [illegible] compounded with fillers, but such compounding increases the stiffness. Thermoplastic rubber does not have to be cured. The dynamic shear modulus is relatively insensitive to temperature over a wide temperature range, [illegible] to 80°C, [illegible] to 176°F). Above 80°C (176°F), the modulus drops rapidly and the material becomes molten at 150°C (302°F). This imposes a service temperature ceiling similar to that for flexible thermoplastics and considerably lower than that for vulcanized rubbers. SBS block copolymers have dynamic properties very [illegible] resilience. The polymer [illegible]

[illegible]

[illegible] natural rubber [illegible]

[illegible] better [illegible] be obtained.

Butyl rubber was used because of its resilience at [illegible] is about as good as natural rubber, as is its tear strength, and the polymer has high damping characteristics at room temperature. Butyl rubber has much better resistance to heat than [illegible] and about the same poor resistance to hydrocarbon fuels. The rubber does not bond readily to reinforcements so developing acceptable adhesion to cables may be a problem.

[illegible] were selected because they have resilience and hot tear [illegible] natural rubber and abrasion resistance as good as or better [illegible] better heat resistance [illegible]

[illegible] those of natural rubber, [illegible] natural rubber, although the [illegible] In addition, [illegible]

[illegible] abrasion [illegible]

[illegible] Tables A. [illegible] Table A. [illegible] Based on [illegible] improved [illegible] flexural fatigue life [illegible] and improved processing [illegible] improvement in flexural fatigue was found.

[illegible] was evaluated for sensitivity to cure pressure using autoclave [illegible] psi and press curing at [illegible] psi; no sensitivity to cure pressure was found.

[illegible]

TABLE A.6 – BROMOBUTYL RUBBER FORMULATIONS*

Ingredients	Formula Designation		
	BAT [illegible]	BAT [illegible]	BAT 605
Bromobutyl [illegible]	60	60	100
Royalene [illegible]	[illegible]	[illegible]	–
SMR [illegible]	[illegible]	25	–
[illegible] polybutadiene		[illegible]	–
N-[illegible] GPF	[illegible]		55
N-[illegible] SRF		[illegible]	–
[illegible]	[illegible]	[illegible]	[illegible]
Naphthenic oil	[illegible]	–	
[illegible]	[illegible]	[illegible]	
[illegible]	–	–	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	10	–
Stearic Acid	1	1	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	–	1.[illegible]	1.[illegible]
[illegible]	1.[illegible]	1.[illegible]	1.[illegible]
[illegible]	1.	–	–
[illegible]	[illegible]	[illegible]	[illegible]

*[illegible] BAT [illegible], SRF-[illegible] for BAT [illegible] for BAT [illegible].

[illegible] BUTYL RUBBER FORMULATIONS*

[illegible]	Formula Designation BAF [illegible]	 BAF [illegible]	 BAF [illegible]
[illegible]	[illegible]	[illegible]	
[illegible]			
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		[illegible]
[illegible]			[illegible]
[illegible]			
[illegible]	[illegible]		
[illegible]			[illegible]
[illegible]		[illegible]	
[illegible]			[illegible]
[illegible]	[illegible]		[illegible]
[illegible]			
[illegible]			
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	

*[illegible]

[illegible]

Ingredient	Formula Designation BAF [illegible]
Neoprene W	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Circo Light Oil	[illegible]
Dioctyl Sebacate	[illegible]
Stearic Acid	[illegible]
Agerite Stalite	[illegible]
Santoflex AW	[illegible]
Sunolite 666	[illegible]
Maglite D	[illegible]
Zinc Oxide	[illegible]
NA 22	.5
Altax	1
Thionex	[illegible].5
Sulfur	0.5

*Phillips Chemical Co., Stowe, OH. Phillips Chemical designation is [illegible].

[illegible]

Formula Designation

RAL [illegible]

[illegible]

[illegible]

[illegible]

[illegible] was reported [illegible]

[illegible] after [illegible]

[illegible]

APPENDIX B

[illegible] POLYURETHANE [illegible]

[illegible]

[illegible]

[illegible], as new materials became available. In some instances, [illegible] new [illegible].

Following [illegible] tests, four formulations were selected and subjected to a series of characterization tests. Ultimately, two of these four formulations were selected for application to [illegible] fabric, and [illegible] quantities of the coated

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Calculation of Curative weight

The following equations may be used to calculate the curative addition required:

$$CL = \text{Curative level per 100 parts prepolymer}$$

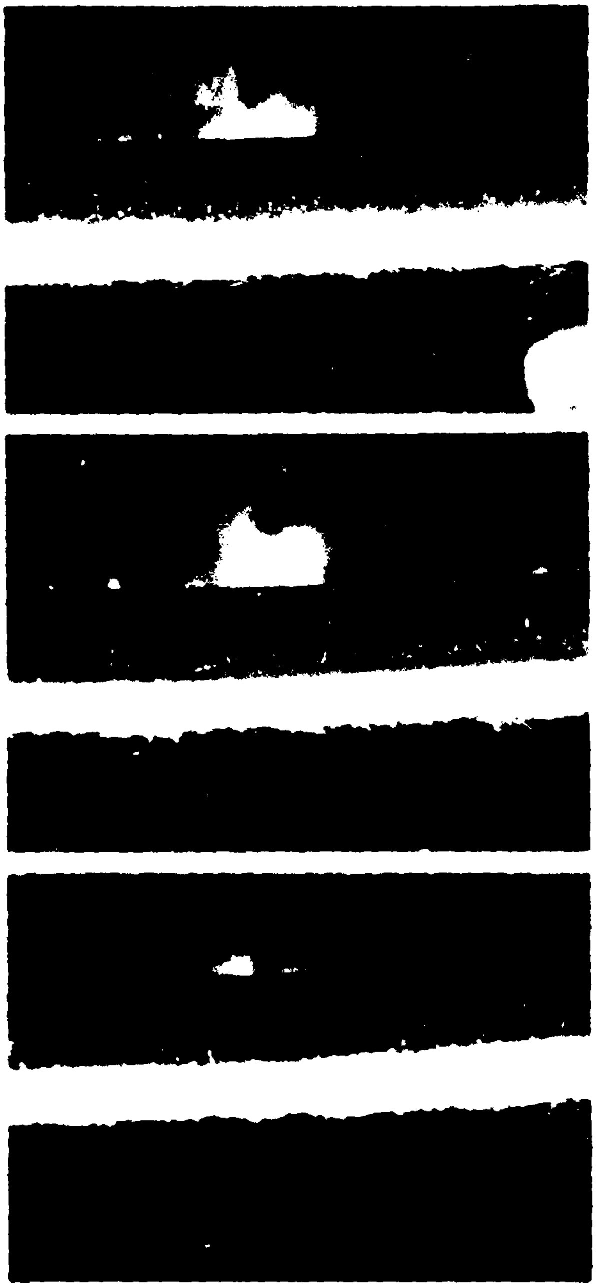
$$= \frac{\text{Percent NCO} \times \text{Equivalent Wt. Curative} \times \text{Curative Mole Ratio}}{4[illegible]}$$

$$\text{Curative Mole Ratio} = \frac{\text{Theoretical Curative Level}}{100}$$

TABLE B.[illegible] - TENSILE STRENGTH OF NYLON AND POLYESTER MAT

[illegible] No.	Material	Weight oz./ft²	Tensile Strength, lb./in.
[illegible]	Nylon Mat	[illegible]	[illegible]
[illegible]	Polyester Mat	[illegible]	[illegible]

[illegible] 11.8, 14.5 Ounces per Square Yard and
[illegible] Polyurethane, Formulation 146

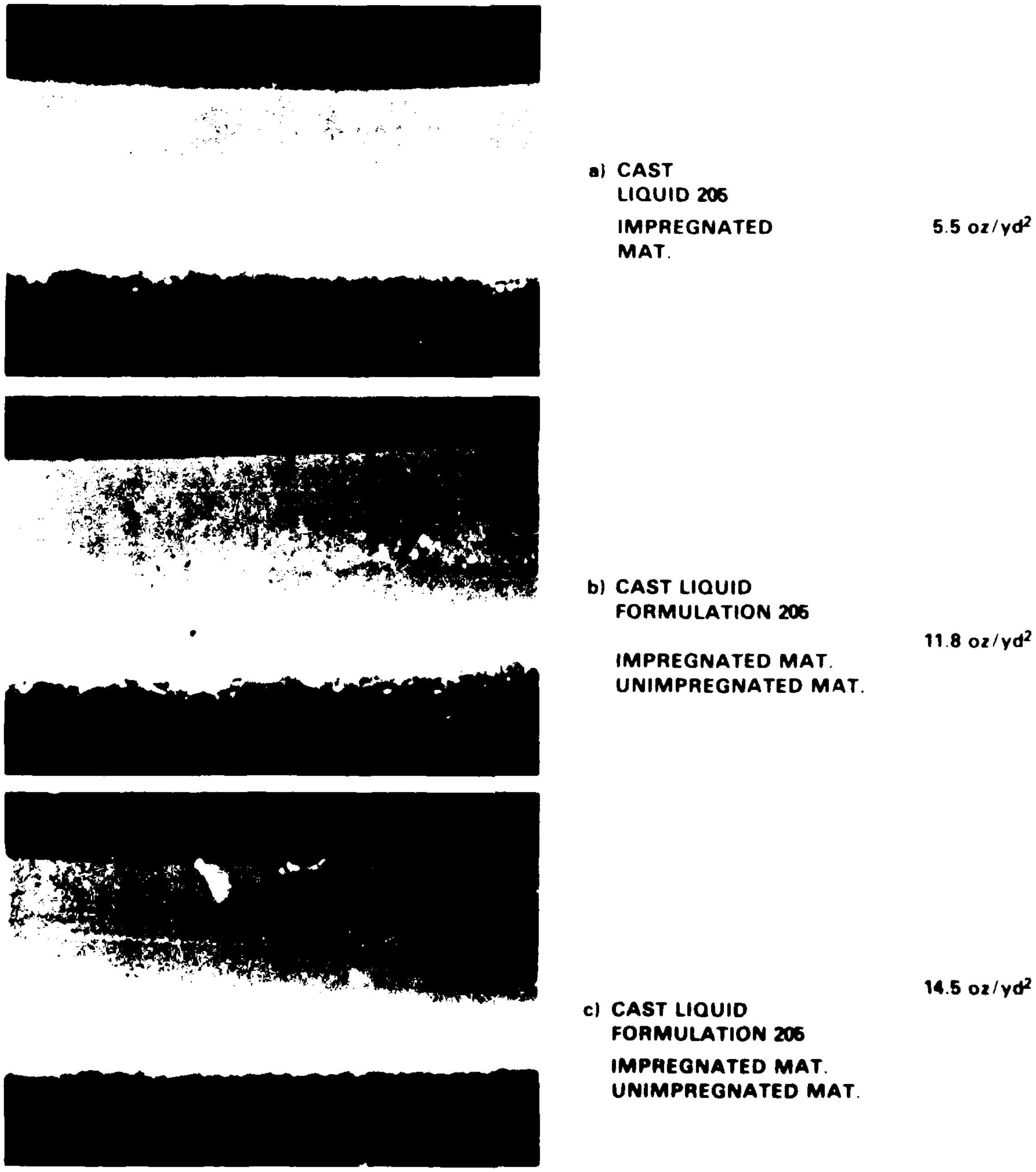


a) POLYURETHANE
FORMULATION 146
COMPLETELY
INFILTRATED MAT.
5.5 oz/yd²

b) POLYURETHANE
FORMULATION 146
95/100% INFILTRATED MAT
11.8 oz/yd²

c) POLYURETHANE
FORMULATION 146
INFILTRATED MAT (50-60%)
UNINFILTRATED MAT (40-50%)
14.5 oz/yd²

Figure B-1 - Permeation of Formulation 205 Polyurethane Into Polyester Mats of Weight 5.5, 11.8 and 14.5 Ounces per Square Yard


a) CAST
LIQUID 205
IMPREGNATED
MAT.
5.5 oz/yd2
b) CAST LIQUID
FORMULATION 205
11.8 oz/yd2
IMPREGNATED MAT.
UNIMPREGNATED MAT.
14.5 oz/yd2
c) CAST LIQUID
FORMULATION 205
IMPREGNATED MAT.
UNIMPREGNATED MAT.

[illegible] prepared [illegible] which [illegible] made of [illegible] [illegible] complete [illegible] [illegible]. It was noted that [illegible] [illegible] adjustment.

[illegible] NATE [illegible]

The [illegible] NCO content is defined as the percent by weight of NCO [illegible] determined by the following [illegible] procedure:

[illegible] sample [illegible] of the prepolymer, transferred to a dry, [illegible] carefully weighed. The sample is then dissolved in [illegible] ml [illegible]. [illegible] ml of 0.1N dibutylamine [illegible] solution is titrated [illegible], to allow [illegible] the effect [illegible] of isopropanol and [illegible] drops of [illegible] indicator,* the liquid is titrated with 0.1N HCl solution to [illegible]. In a similar manner, a "blank" is run using all reagents [illegible].

[illegible] content is then determined using the following calculation:

$$\text{Percent NCO} = \frac{(B - S) \times N \times 4.2}{\text{Weight of Sample (g)}}$$

where B = Volume of 0.1N HCl required for blank (ml)

S = Volume of 0.1N HCl required for sample (ml)

N = Normality of HCl solution

---

*Bromophenol Blue Indicator: Dissolve 0.1 g dry bromophenol blue in 1.5 ml 0.1N NaOH and dilute to 100 ml with distilled water.

Formulation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Dullanox Silica	[illegible]	[illegible]	F
208	PTMEG 2000	$H_{12}MDI$	MOCA	[illegible]	[illegible]	–		–	[illegible]	[illegible]
209	PTMEG 2000	$H_{12}MDI$	MOCA	[illegible]	[illegible]	–		[illegible]	[illegible]	[illegible]
210	[illegible]	$H_{12}MDI$	[illegible]	[illegible]	[illegible]	[illegible]		–	[illegible]	[illegible]
211	[illegible] PTMG 2000	MDI	[illegible]	[illegible]	[illegible]	–	–	–	[illegible]	[illegible]
	[illegible] Hexanediol [illegible]									

[illegible]

[illegible]

[illegible] different weights were tested [illegible] to establish the degree of infiltration possible with each type of material. The results are shown in Figure 5.1. The degree of permeation achieved was as follows:

1.5 oz yd² mat - approximately [illegible] permeation

11.8 oz yd² mat - approximately 60% permeation

5.5 oz yd² mat - approximately 95-100% permeation.

TASK 2 - HOMOGENEOUS MATERIALS DEVELOPMENT

In order to prepare specimens for evaluation in this task, the handling procedures for the polyurethane polymers had to be modified. The addition of 5% carbon black or [illegible] fumed silica increased the viscosity of the prepolymers to such an extent that the additives could not be added either by simple stirring or in a paint mill.

For formulation PU-2[illegible] (BAI-146 + 5% carbon black + 5% fumed silica), approximately [illegible] of xylene was added to reduce the viscosity, and a satisfactory dispersion was obtained by milling on a paint mill. This material was then stirred with a high-torque low-speed stirrer under vacuum to remove the solvent. Analysis of the prepolymer indicated a 2.95% isocyanate content (compared to 3.6% normally expected for this material). The lower NCO figure may have been due to reaction of the isocyanate group with atmospheric moisture, since a large surface area of the prepolymer is exposed during milling. The correct calculated quantity of curative was subsequently incorporated into the prepolymer and the material was successfully cast into a 1-yd² sheet.

For PU-211 (PU-2[illegible] + 5% carbon black) a slightly different approach was adopted in the modification procedure. The modification was to incorporate the 5% carbon black into the polyurethane prepolymer and, separately, blend the 5% fumed silica into the butane diol chain extender. The two modified components were then to be mixed in a "Semkit" cartridge dispenser, and extruded followed by molding in dies to form [illegible] ft² sheets.

The carbon black was successfully incorporated into the prepolymer. However, blending the 5% SiO_2 into the butane diol was found to be impossible, since only a small quantity is necessary to satisfy the stoichiometric requirements of the prepolymer (for a prepolymer of [illegible] NCO content, this would amount to about [illegible] g of butane diol per 1[illegible] g of prepolymer). Consequently, a compromise was made, and the material was cast containing the carbon black only.

For PU-21[illegible] (PU-198 + 5% carbon black and 5% silica) the addition of approximately [illegible] xylene was necessary, and curing of the polymer was considerably retarded by the presence of the solvent, even though this system was catalyzed with T-12 catalyst. Oven post-cure of this material was delayed until most of the solvent had diffused out; otherwise voids would have been formed by the solvent vapor.

[illegible]

[illegible]

[illegible] it was necessary to cure this material during the [illegible] properties which existed when the polymer was [illegible] that the results for the material allowed to gel [illegible] were [illegible] than those for material allowed to gel while [illegible] indicates that atmospheric moisture may also have had [illegible] of polyurethanes which cure slowly since [illegible] moisture [illegible] to diffuse into the gelled polymer and react with free isocyanate groups.

The full potential of this formulation can be obtained only when the material is heat-cured immediately in closed dies.

[illegible] In addition to the formulation work performed [illegible], one additional system was investigated. This was an [illegible] formulation BAI [illegible], but substituting a PPMO of m.w. [illegible] BAI [illegible]. Other parameters such as NCO/OH [illegible]. The purpose of this investigation was [illegible] BAI [illegible] but with the lower modulus [illegible] of a [illegible] material of higher molecular [illegible].

[illegible], was subsequently evaluated through screening [illegible] characterization test evaluation.

[illegible] Coated Woven Fabrics

[illegible] characterization testing, two polyurethane formulations, [illegible] were selected and used to prepare coated fabric samples. [illegible] as described earlier for the [illegible] rubber polymer work. [illegible] were [illegible] in a size of 1 yd². Prior to use, the 1-yd² [illegible] were [illegible] three times in methyl ethyl ketone to remove any contami[illegible] at room temperature. The fabric was then treated [illegible] acetone and allowed to dry.

[illegible] fabric was coated with the liquid elastomer using [illegible]. Previous work at BAI demonstrated that, [illegible] thicknesses could be applied [illegible] the fiber-bundle intersections, in spite of [illegible] of the liquid rubber. After gelling, the partially [illegible] fabric sections were turned over and coated on the opposite side. [illegible], the composite sheets were post-cured at 100°C (212°F) for [illegible] hr.

[illegible], were prepared for testing at BAI, and for delivery to the Center for evaluation. In addition to the coated fabric specimens, 1-yd² sheets of the [illegible] were also prepared for delivery to the Center.

In the case of polyurethane formulation [illegible], a difference in processing was necessary in the fabrication of large size (1 yd²) sheets of the fabric reinforced material which were required. Whereas the properties of the original formulation [illegible] were derived from test sheets prepared by heat curing of the liquid elastomer [illegible] immediately after casting, the polymers applied to the 1-yd² sheets of fabric were allowed to gel overnight to facilitate handling; they were then oven-cured at 100°C (212°F) for 3 hr.

[illegible]

[illegible]

[illegible] tried.

[illegible] effective [illegible] introduced. [illegible] elastomeric properties. [illegible] silanes was [illegible] readily [illegible] effectively blocking [illegible] the A-[illegible] epoxy [illegible] reactive [illegible] groups present in this material. [illegible] modification of the [illegible] (Table [illegible]); this synthesis proceeded satisfactorily. [illegible] was designated formulation [illegible].

[illegible] BAI-1[illegible], [illegible], one further elastomer was [illegible] of A-186 silane; this was a supplementary formulation, [illegible] under "Miscellaneous Supplementary Work." The elastomer was analogous to formulation BAI-146, but featured the use of a PTMEG of m.w. 29[illegible] as a substitution for PTMEG of m.w. [illegible]; NCO:OH ratio and curative level were unchanged. This silane-modified elastomer was designated [illegible].

PBD	R45M				CS15			
NCO	IPDI		$H_{12}MDI$		IPDI		$H_{12}MDI$	
Curative	BDO	MDA	BDO	MDA	BDO	MDA	BDO	MDA
Elastomer	19[illegible]	191	187	186	19[illegible]	189	18[illegible]	184

In general, all four prepolymers, when treated with MDA as a curative, reacted [illegible] too rapidly [illegible] to yield opaque light brown rubbery materials [illegible] films. The short reaction times automatically eliminated these materials from further consideration.

[illegible] same prepolymers, when treated with BDO as a curative, reacted so slowly that it was necessary to catalyze the reaction with [illegible] catalyst. These [illegible] were allowed to gel overnight and were then post-cured at [illegible]. These were yielded [illegible] low modulus elastomers, 185, 187, [illegible] and [illegible] as shown in Appendix C.

The work in this phase was supplemented as follows: An additional [illegible] elastomer, 184, was formulated at a higher NCO:OH ratio of [illegible] to prepare a[n] elastomer [illegible] higher modulus. Generally, these materials did not possess adequate tensile [illegible] with [illegible].

[illegible] with personnel at the Center, it was agreed to further evaluate [illegible] two additional curing agents, Isonol [illegible], N,N-bis [illegible] 2-ethyl 1:3 hexane diol with a potential yield of [illegible]. In spite of catalysts and attempted heat-curing, the prepolymers [illegible] prepolymer R45M yielded only gummy products; those from [illegible] were more promising, and led to an additional four elastomers [illegible] formulating the prepolymers at an NCO:OH ratio of [illegible] according to the following experimental plan.

	CS 15			
	IPDI		$H_{12}MDI$	
[illegible]	2 et. 1:3*	Isonol	2 et. 1:3*	Isonol
[illegible]	199	200	197	198

*2-ethyl 1:3 hexane diol

[illegible]

[illegible] stability of a Bell [illegible]

[illegible]

[illegible] propellants. Each of the propellants [illegible] (MDA). [illegible] design is shown below and has a potential yield of eight elastomers.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

Property to be Measured	Standard Test Method
[illegible]	ASTM [illegible]
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	ASTM [illegible]
[illegible]	ASTM [illegible]
[illegible]	ASTM [illegible] Modified*
[illegible]	[illegible] ASTM [illegible] Method A
[illegible]	[illegible] ASTM [illegible]
[illegible]	[illegible] ASTM [illegible]
[illegible]	Appendix B ([illegible] Specimens only)

*[illegible] strip [illegible].

[illegible]

Property to be Measured	Standard Test Method
[illegible]	ASTM [illegible]
[illegible] and Water	ASTM [illegible]

TABLE [illegible]. SUMMARY OF EVALUATION TESTS FOR RUBBER COATED FABRICS

Property to be Measured	Standard Test Method
Ultimate Tensile and Tongue Tear	ASTM [illegible] Method B Tongue Tear ASTM [illegible]*
Ply Adhesion	ASTM [illegible] (Modified)
Flexural Fatigue	DeMattia ASTM [illegible]
Constant Low Strain [illegible] Tensile Fatigue	DeMattia ASTM [illegible]
Water Wicking	Weight Gain

*A Neoprene coated nylon fabric backing strip was bonded to the rubber.

APPENDIX D

DETAILED EXPERIMENTAL DATA

This appendix presents more detailed experimental data from which the averaged results were calculated and presented in the text. In most cases, the results for each test specimen are tabulated; in a few cases where the numerical spread in data was small, the maximum and minimum values are tabulated in addition to the average value, rather than each individual data point. Usually 3 to 5 data points were included in each average value.

In Tables D.1 and D.2 are presented the crack growth and flexural fatigue data for the 7 gum rubber polymers and the 4 castable liquid polyurethane polymers, respectively. Results are presented for each of the three specimens which were evaluated for each polymer, and the generally large spread in results of this type of test is obvious.

Tables D.3 and D.4 contain the mechanical characterization data for the 7 gum rubber polymers and the 4 castable liquid polyurethane polymers which were selected for this phase of the program. Table D.5 presents the coating adhesion data. Tables D.6 and D.7 contain the Pico abrasion test results for the 7 gum rubber polymers and the 4 castable liquid polyurethane polymers. Experimental results from the duplicate specimens which were evaluated with the Goodrich Flexometer hysteresis test are listed in Tables D.8 and D.9 for the gum rubbers and polyurethanes, respectively. Plots of the temperature rise versus time for the various polymers are presented in Figures D.1, D.2, D.3, D.4, D.5, D.6, and D.7 for the gum rubbers and in Figures D.8, D.9, and D.10 for the polyurethane polymers.

More details of the experimental data characterizing the effects of water on the polymers are presented in Tables D.10 and D.11. Similarly, the effects of [illegible] immersion are presented in Tables D.12 and D.13.

Tensile and elongation data for each specimen at three different test temperatures are presented in Table D.14 for the gum rubber polymer coated nylon fabric laminate and for the castable polyurethane polymer coated nylon fabric laminate in Table D.15. Similarly, tear strength results are presented in Tables D.16 and D.17. Coating adhesion results are presented in Table D.18 for polyurethane coated nylon fabric; the fabric and adhesion promoter were the same as used in the previous coating adhesion tests.

Results for the triplicate specimens of polymer coated nylon fabric laminates were evaluated for flexural fatigue resistance in the DeMattia test are presented in Tables 9.19 and 9.[illegible].

Salt water weathering and absorption results are presented as a function of exposure time in Figures 9.11 and 9.12.

Results for [illegible] coated [illegible] warp fabric composite specimens are presented in Tables 9.21 (tensile strength), 9.22 (tear strength), and 9.23 (coating adhesion).

TABLE [illegible] – [illegible]

Polymer Designation	Number of [illegible] 200% Growth 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BAT-146	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***
PI-183	160***	[illegible]***	[illegible]***			
PI-185	800***	[illegible]***	[illegible]***	[illegible]	[illegible]	[illegible]
PI-187	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***
PI-188	[illegible]***	[illegible]***	[illegible]	[illegible]	[illegible]	[illegible]
PI-192	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PI-195	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PI-196	200***	[illegible]***	[illegible]***	[illegible]	[illegible]	[illegible]
PI-198	600***	[illegible]***	[illegible]***	[illegible]	[illegible]	[illegible]
PI-198-2	400***	[illegible]***	[illegible]***	[illegible]	[illegible]	[illegible]
PI-204	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***
PI-205	1,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PI-206	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***	[illegible]***

* [illegible] rate [illegible]

** Crack initiated [illegible] toward the thickness [illegible] thickness, the [illegible] 1.5 mm (sample thickness [illegible]).

*** Results were estimated [illegible]

+Full width crack [illegible]

++One-half width crack [illegible]

[illegible]

[illegible] Mn PTMEG	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Mn [illegible] Mn)	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] compound [illegible]

AD A151 438 FINGER MATERIALS FOR AIR CUSHION VEHICLES VOLUME 1 FLEXIBLE COATINGS FOR..(U) BELL AEROSPACE TEXTRON BUFFALO NY P K CONN ET AL. DEC 84 7467-927048-VOL-1

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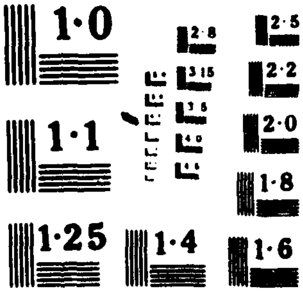

1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
1·8
1·25
1·4
1·6

TABLE D.13 - MECHANICAL PROPERTIES OF POLYURETHANE FORMULATIONS BEFORE AND AFTER IMMERSION IN [illegible] FUEL*

Formu-lation No.	Formulation Type: Diol	Formulation Type: Di-Isocyanate	Formulation Type: Curative	Hardness	Tear Strength	Modulus	Modulus	Tensile Strength	Tensile	Hardness	After Immersion: Modulus	After Immersion: Modulus	After Immersion: Ultimate Tensile Strength	After Immersion: Ultimate	After Immersion: Volume Change
183	2900 MW PTMEG	H MDI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
185	PBD Styrene Copolymer	H MDI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
198	PBD Styrene Copolymer	H MDI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
205	70% PTMEG (2000 MW) 30% Poly-carbonate	MDI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Immersed for one week at room temperature.

TABLE D.14 - TENSILE RESULTS FROM RUBBER/ WOVEN NYLON COMPOSITE

11	-1	(3[illegible])	[illegible]	1140	38	[illegible]
12	-1	(300)	1060		31	
13	-1	(300)	1160			
14	-1	(300)	1193		31	
15	-1	(300)	1133		30	

TABLE D.14 - (Continued)

[illegible]	[illegible]	[illegible]	Test Temperature °C (°F)	Tensile Strength lbs./in.	Average	Elongation %	Average
		[illegible]	24 (75)	1020	1062	33	26
			24 (75)	1086		23	
			24 (75)	993		25	
			24 (75)	1072		31	
			24 (75)	1072		30	
			49 (120)	1033	[illegible]	25	29
			49 (120)	1112		30	
			49 (120)	[illegible]		30	
			49 (120)	[illegible]		28	
			49 (120)	1086		31	
			-1 (30)	1180	[illegible]	–	[illegible]
			-1 (30)	1086		21	
			-1 (30)	[illegible]		[illegible]	
			-1 (30)	1200		–	
			-1 (30)	1142		20	
[illegible]		[illegible]	24 (75)	1033	1003	30	[illegible]
			24 (75)	[illegible]		31	
			24 (75)	987		28	
			24 (75)	1006		28	
			24 (75)	1033		28	
			49 (120)	1020	[illegible]	40	[illegible]
			49 (120)	1039		38	
			49 (120)	1086		[illegible]	
			49 (120)	1092		38	
			49 (120)	1020		[illegible]	
			-1 (30)	1106	[illegible]	–	32
			-1 (30)	920		28	
			-1 (30)	894		[illegible]	
			-1 (30)	987		[illegible]	
			-1 (30)	981		[illegible]	
		[illegible]	24 (75)	987	1029	14	[illegible]
			24 (75)	1086		19	
			24 (75)	987		[illegible]	
			24 (75)	1033		[illegible]	
			24 (75)	1033		20	
			49 (120)	1003	1033	28	[illegible]
			49 (120)	1006		26	
			49 (120)	1020		26	
			49 (120)	1099		30	
			49 (120)	1036		30	

TABLE D.14 - (Continued)

Material	Specimen No.	Weave Direction	Test Temperature °C (°F)	Tensile Strength lbs. in.	Average	Elongation %	Average
	11		-1 (30)	1092	1068	35	25
	12		-1 (30)	1032		-	
	13		-1 (30)	1284		20	
	14		-1 (30)	924		32	
	15		-1 (30)	1041		14	
BAF 418	1	Warp	24 (75)	1127	1130	44	44
	2		24 (75)	1054		40	
	3		24 (75)	1171		44	
	4		24 (75)	1151		36	
	5		24 (75)	1151		46	
	6		49 (120)				
	7		49 (120)				
	8		49 (120)	Testing cancelled,			
	9		49 (120)	material softened.			
	10		49 (120)				
	11		-1 (30)				
	12		-1 (30)				
	13		-1 (30)	Testing cancelled.			
	14		-1 (30)				
	15		-1 (30)				
	1	Fill	24 (75)	1218	1221	30	30
	2		24 (75)	1224		30	
	3		24 (75)	1125		30	
	4		24 (75)	1220		29	
	5		24 (75)	1316		29	
	6		49 (120)	1152	1176	25	28
				Rubber covering gave-way first pull; spec. repositioned and test completed.			
	7		49 (120)	1289		32	
				(Test temperature = 110°F) first test at 120°F; rubber gave-way.			
	8		49 (120)	Rubber covering softened and was separated from fabric by grip.			
	9		49 (120)	1089		26	
				(Test Temperature = 110°F)			
	10		49 (120)				
	11		-1 (30)	Testing cancelled.			
	12		-1 (30)				
	13						
	14						
	15						

TABLE D.1[illegible] - TENSILE RESULTS FROM POLYURETHANE WOVEN NYLON COMPOSITE

Material	Specimen No.	Weave Direction	Test Temperature °C (°F)	Material Thickness in.	Tensile Strength lbs./in.	Elongation %
[illegible] - Nylon Fabric	1	Warp	24 (75)	[illegible]	1040	35
	2	Warp	24 (75)	0.185	1100	[illegible]
	3	Warp	24 (75)	0.190	1160	30
					Avg. 1100	Avg. 37
	4	Warp	49 (120)	0.172	1150	40
	5	Warp	49 (120)	0.198	1030	40
	6	Warp	49 (120)	0.195	1100	35
	7	Warp	49 (120)	0.207	1040	3[illegible]
					Avg. 1080	Avg. 37
[illegible] - Nylon Fabric	1	Fill	24 (75)	0.185	830	29
	2	Fill	24 (75)	0.186	1180	2[illegible]
	3	Fill	24 (75)	0.185	1170	30
	4	Fill	24 (75)	0.191	1290	2[illegible]
					Avg. 1120	Avg. [illegible]
	[illegible]	Fill	49 (120)	0.168	1120	30
	6	Fill	49 (120)	0.172	920	3[illegible]
	7	Fill	49 (120)	0.186	1170	28
	8	Fill	49 (120)	0.187	1000	22
					Avg. 1070	Avg. 2[illegible]
183 - Nylon Fabric	1	Warp	24 (75)	0.140	1140	3[illegible]
	2	Warp	24 (75)	0.139	1180	30
	3	Warp	24 (75)	0.139	1060	30
	4	Warp	24 (75)	0.140	1240	35
					Avg. 11[illegible]0	Avg. 3[illegible]
	5	Warp	49 (120)	0.140	1060	32
	6	Warp	49 (120)	0.144	1040	40
	7	Warp	49 (120)	0.146	1100	3[illegible]
	8	Warp	49 (120)	0.146	1080	32
					Avg. 1080	Avg. 34
183 - Nylon Fabric	1	Fill	24 (75)	0.16[illegible]	1190	2[illegible]
	2	Fill	24 (75)	0.170	1100	22
	3	Fill	24 (75)	0.169	1120	26
	4	Fill	24 (75)	0.170	1220	25
					Avg. 1160	Avg. 25
	5	Fill	49 (120)	0.151	950	2[illegible]
	6	Fill	49 (120)	0.150	87[illegible]	23
	7	Fill	49 (120)	0.152	970	28
	8	Fill	49 (120)	0.150	1030	22
					Avg. 960	Avg. 25

[illegible]

Material	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RAT [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RAT [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RAT [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]

** [illegible]

*** [illegible]

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Material Description		Test Temperature °C	(°F)	Crack Initiation	[illegible]	[illegible]	[illegible]
FCB 402 Nylon	Warp	4	(40)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
		49	(120)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
	Fill	4	(40)	[illegible]	[illegible]	[illegible]	[illegible]
		49	(120)	2x10^6	[illegible]	[illegible]**	[illegible]**
BAT 403 Nylon	Warp	4	(40)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
		49	(120)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
	Fill	4	(40)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
		49	(120)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
BAT [illegible] Nylon	Warp	4	(40)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
		49	(120)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
	Fill	4	(40)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
		49	(120)	2x10^6 (all three specimens)	[illegible]	[illegible]	[illegible]
BAT 428 Nylon	Warp	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Fill	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		49	[illegible]	[illegible]***	[illegible]***	[illegible]***	[illegible]***

*The data [illegible]

**Specimens exhibited [illegible]

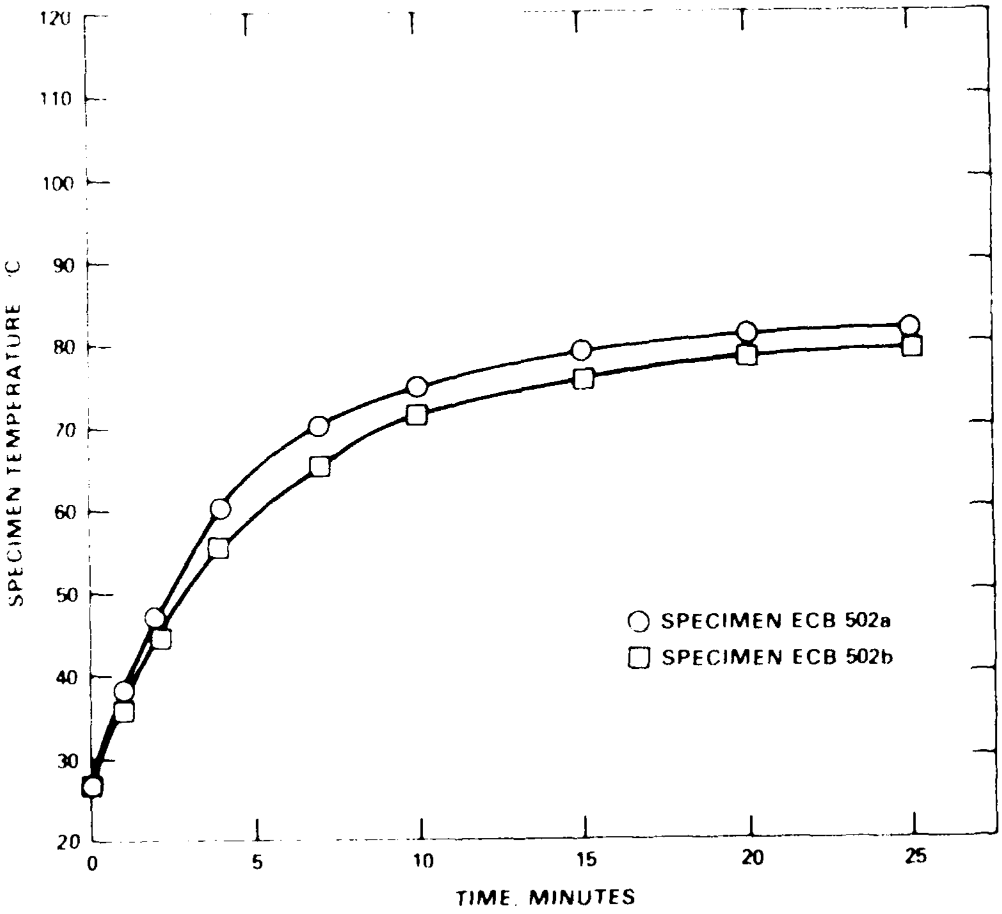
***Specimens exhibited wear [illegible]

[illegible] FROM POLYURETHANE-POLYESTER FAST COMPOSITE

[illegible]

[illegible] HANE-POLYESTER FAST COMPOSITE

Material	Specimen	High	Low	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	108	116
	[illegible]	[illegible]	117	118



120
110
100
90
80
70
60
50
40
30
20
SPECIMEN TEMPERATURE °C
0
5
10
15
20
25
TIME, MINUTES
○ SPECIMEN ECB 502a
☐ SPECIMEN ECB 502b

[illegible]

[illegible]

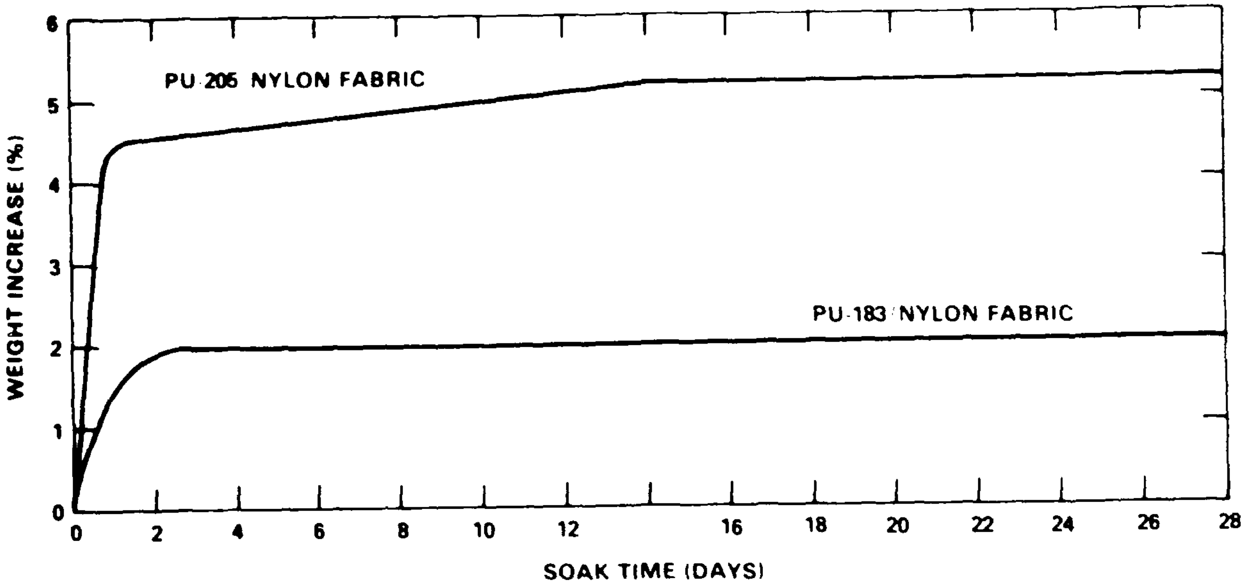
[illegible]	[illegible]
[illegible]	[illegible] Company [illegible] [illegible] [illegible]
[illegible]	[illegible] [illegible]
[illegible]	[illegible] [illegible] [illegible] Street [illegible] [illegible]
[illegible]	[illegible] [illegible] Department [illegible] [illegible]
[illegible]	[illegible] [illegible] Drive, N.E. Atlanta, GA [illegible]
[illegible]	Cabot Corporation Cab-O-Sil Division P.O. Box 188 Tuscola, IL 61953
[illegible]	CIBA-GEIGY Corporation Plastics and Additives Division Saw Mill River Road Ardsley, NY [illegible]
[illegible]	Columbian Chemicals Company [illegible] W. Market Street Akron, OH [illegible]
[illegible]	The C.P. Hall Company 7300 South Central Avenue Chicago, IL 60638
[illegible]	Dow Chemical Company 2030 Dow Center Midland, MI 48640

[illegible]

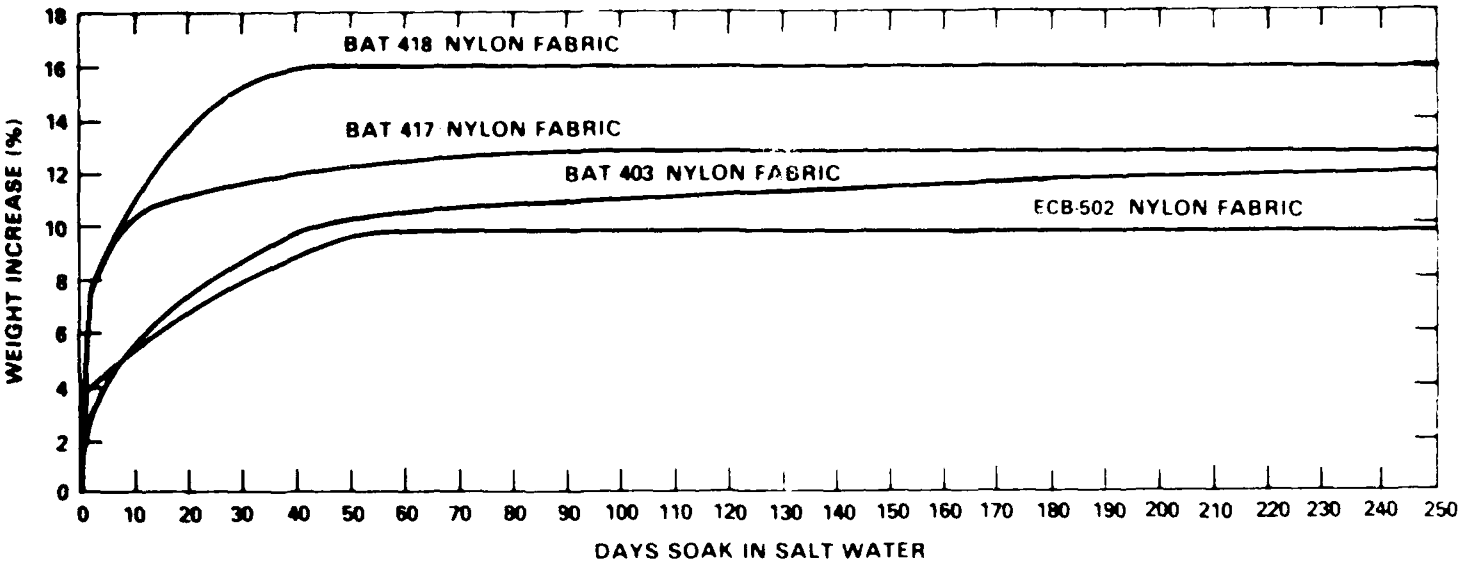
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

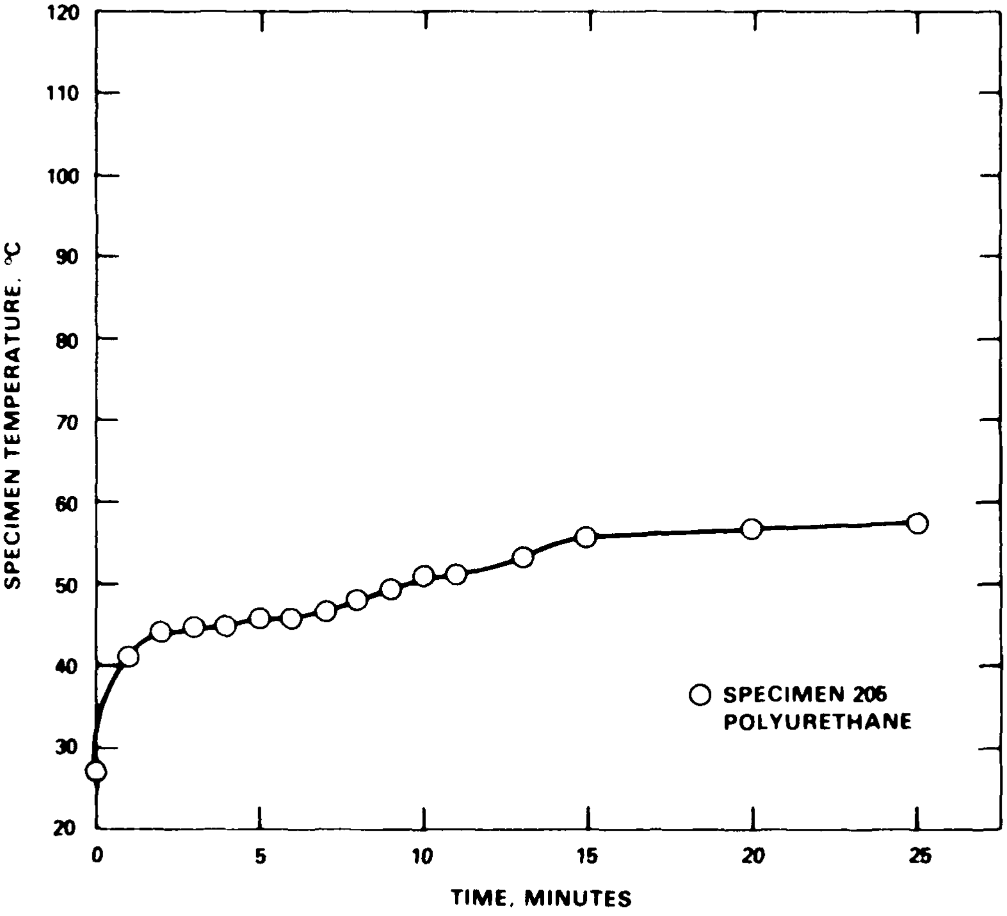
[illegible]

[illegible] the [illegible] tested are shown in the following table.


PU 205 NYLON FABRIC
PU 183 NYLON FABRIC
WEIGHT INCREASE (%)
0
1
2
3
4
5
6
SOAK TIME (DAYS)
0
2
4
6
8
10
12
16
18
20
22
24
26
28

[illegible]


BAT 418 NYLON FABRIC
BAT 417 NYLON FABRIC
BAT 403 NYLON FABRIC
ECB-502 NYLON FABRIC
WEIGHT INCREASE (%)
0
2
4
6
8
10
12
14
16
18
DAYS SOAK IN SALT WATER
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250



[illegible] Temperature Rise During [illegible] Loading at [illegible] per Minute Superimposed on [illegible] Loading of 1.4 Pounds per Square Inch

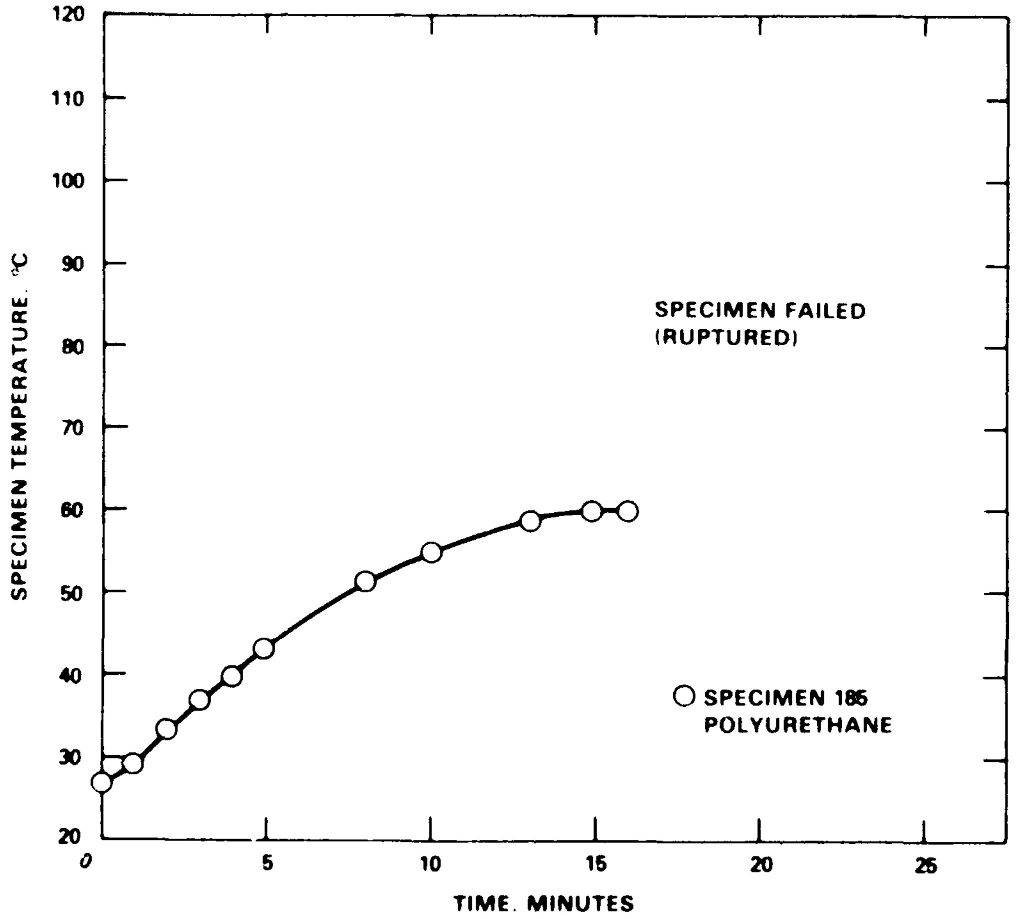


Figure [illegible]. Specimen Temperature Rise During Cyclic Compressive Loading at [illegible] Cycles per Minute Superimposed on a Compressive Loading of [illegible] Pounds per Square Inch

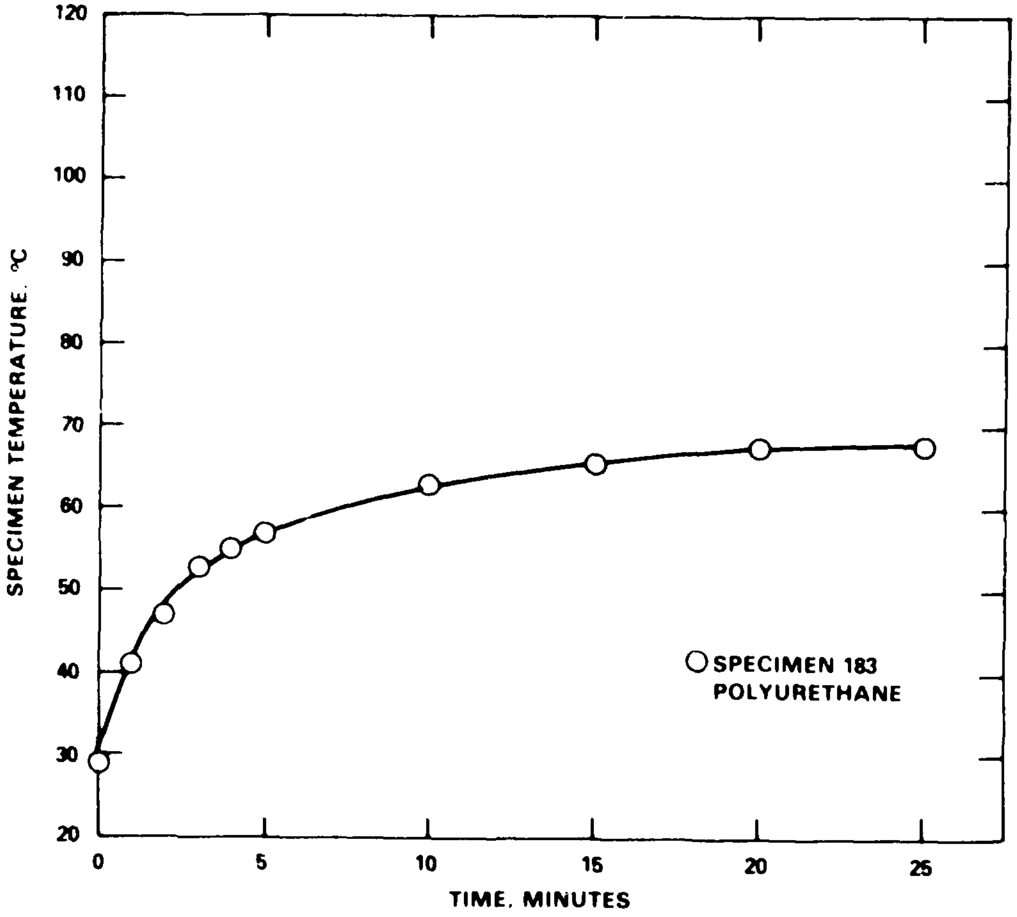
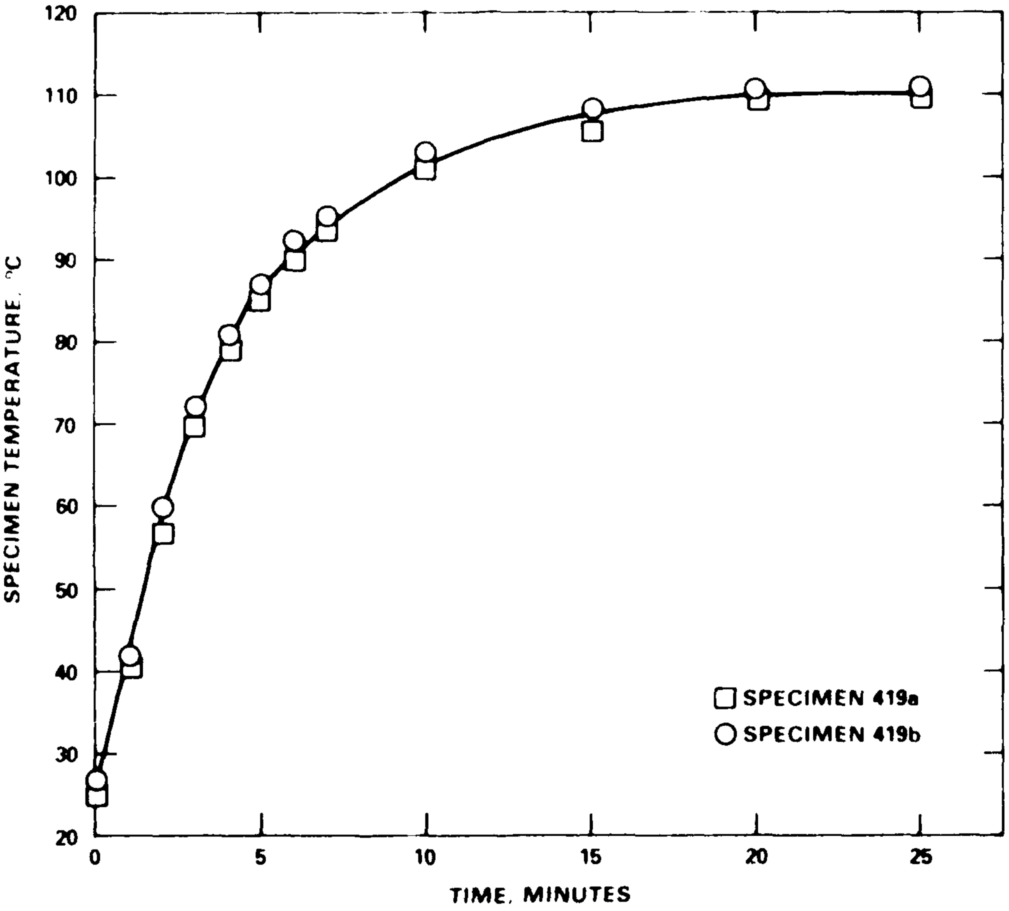
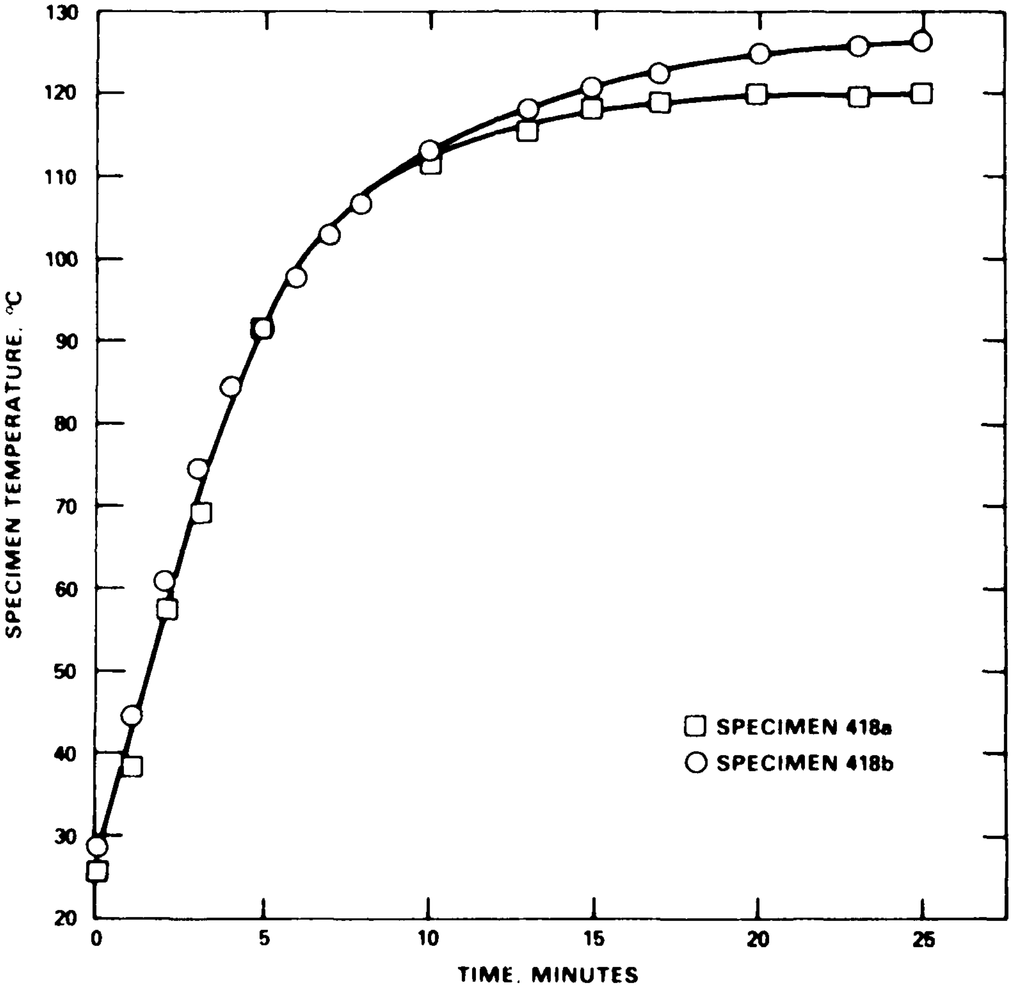


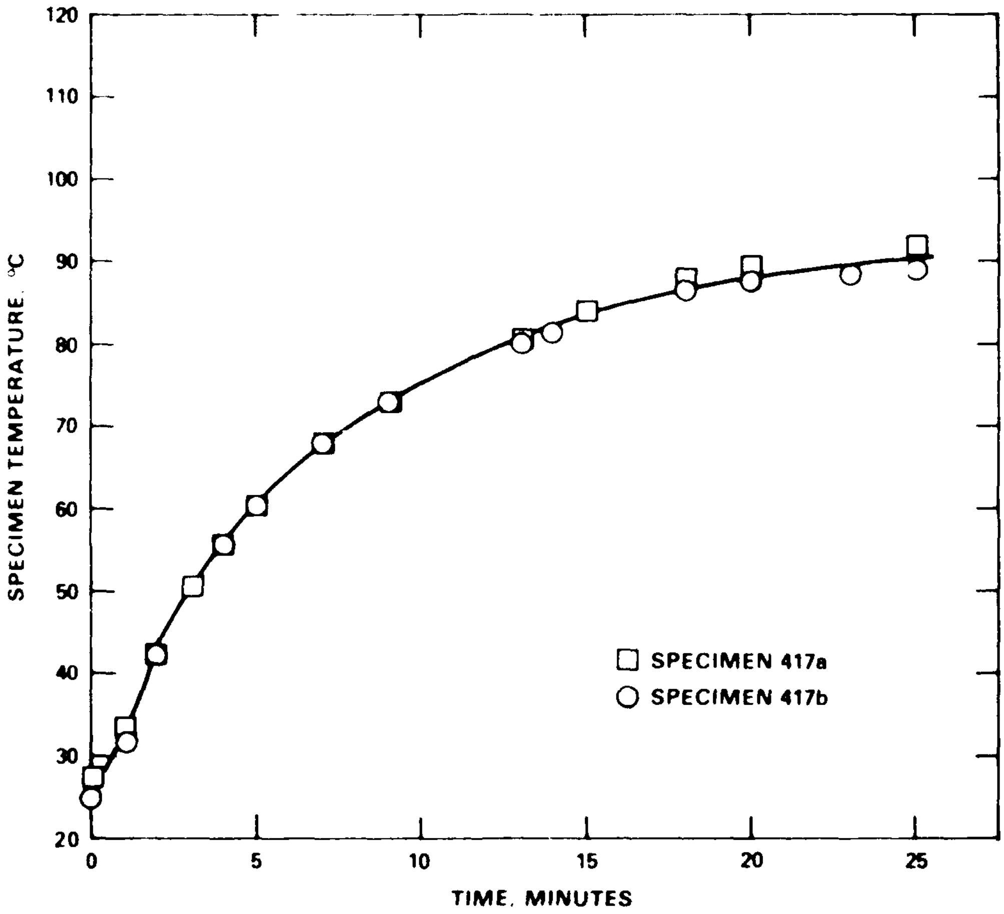
Figure [illegible]. Specimen Temperature Rise During Cyclic Compressive [illegible] of 1000 Cycles per Minute Superimposed on a Compressive Loading of 1.5 Pounds per Square Inch


120
110
100
90
80
70
60
50
40
30
20
SPECIMEN TEMPERATURE, °C
0
5
10
15
20
25
TIME, MINUTES
□ SPECIMEN 419a
○ SPECIMEN 419b

[illegible]
[illegible]
[illegible]



[illegible] Compressive
[illegible] Minute [illegible] Compressive
[illegible] Square Inch


120
110
100
90
80
70
60
50
40
30
20
SPECIMEN TEMPERATURE, °C
0
5
10
15
20
25
TIME, MINUTES
□ SPECIMEN 417a
○ SPECIMEN 417b

[illegible]

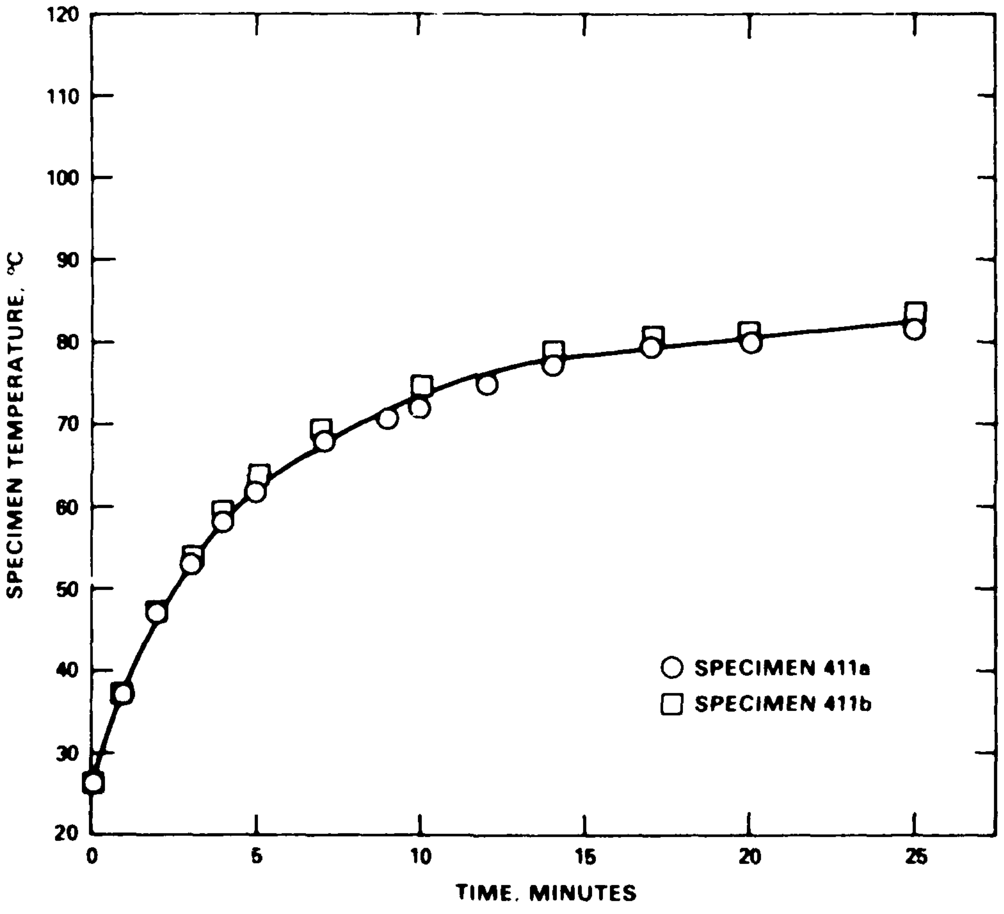
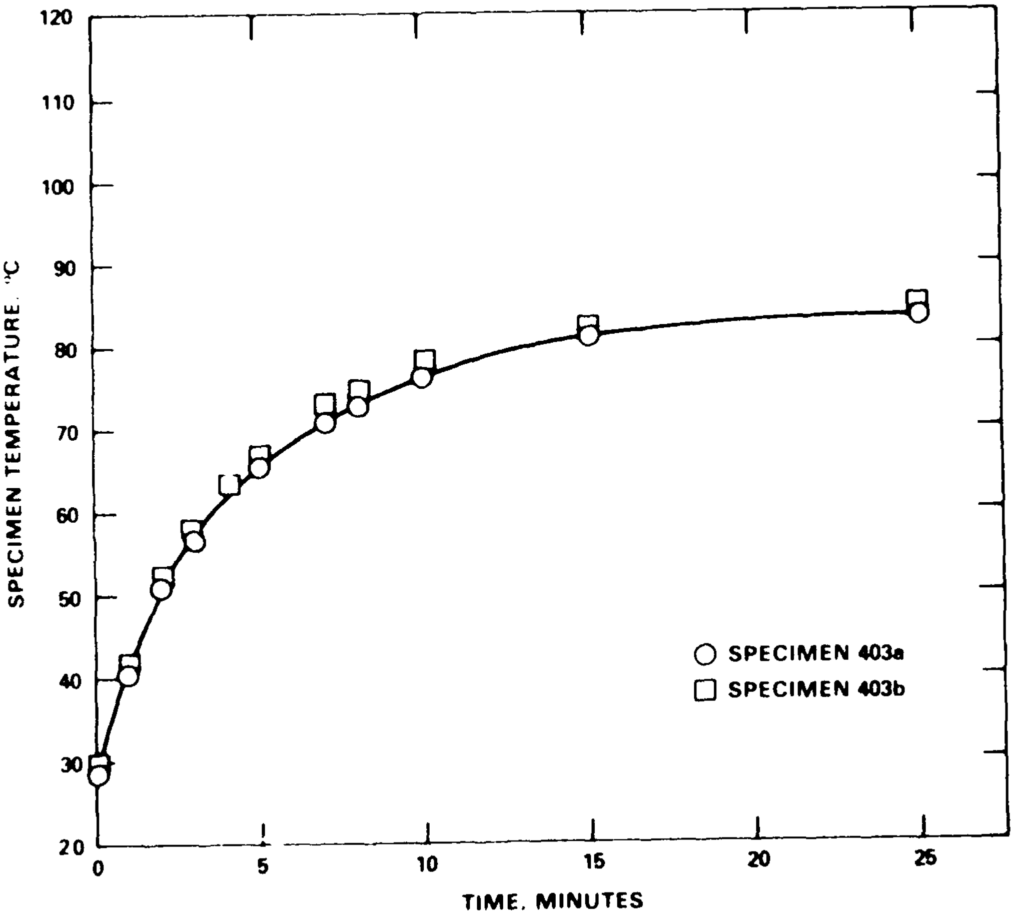
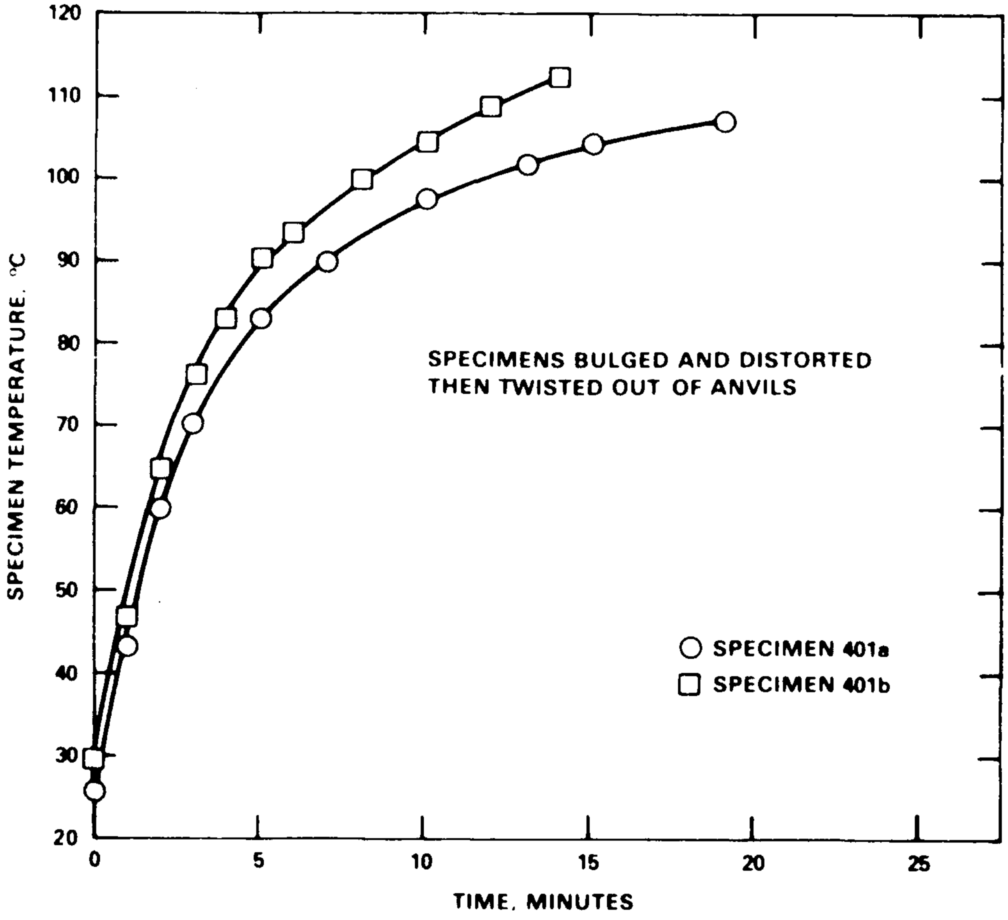


Figure [illegible]. Hysteresis (Temperature Rise) During Cyclic Compressive Loading at 1,000 Cycles per Minute Superimposed on a Compressive Load of 143 Pounds per Square Inch



[illegible] Temperature Rise During [illegible] Compressive [illegible] per Minute Superimposed on a Compressive Loading of [illegible] Pounds per Square Inch



[illegible] Specimen Temperature versus Time during Cyclic Compressive
Loading at 1000 [illegible] per Minute Superimposed on a Compressive
Preload of 1-5 Pounds per Square Inch

Hypalon Kevlar NA-22 Neoprene GNA Neoprene W Tetrone A Thionex	E.I. duPont de Nemours & Co., Inc. Wilmington, DE 19898
Antioxidant 702	Ethyl Corporation 451 Florida Street Baton Rouge, LA 70801
Wingstay 100	Goodyear Tire & Rubber Company Chemical Division 1485 E. Market Street Akron, OH 44316
STAN MAG Beads	Harwick Chemical Corporation 60 S. Seiberling Street P.O. Box 9360 Akron, OH 44305
Parel 58 Piccopale 100	Hercules Incorporated 910 Market Street Wilmington, DE 19899
T.12	M&T Chemical Incorporated Woodbridge Road P.O. Box 1104 Rahway, NJ 07065
Antioxidant MB Polycarbonate (Desmophen 2020)	Mobay Chemical Company Penn Lincoln Parkway West Pittsburgh, PA 15205
Santicizer 79TM Santicizer 711 Santocure Santocure NS Santoflex AW Santoguard PVI Sulfasan R	Monsanto Rubber Chemicals Division 260 Springside Drive Akron, OH 44313
Cumar MH	Neville Chemical Company Neville Island Pittsburgh, PA 15225
Kadox-15	New Jersey Zinc Company, Inc. Palmerton, PA 18071

[illegible] [illegible]	Phillips Chemical Company A Division of Phillips Petroleum Company 12[illegible] Phillips Building Bartlesville, OK [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]	Polysar Limited [illegible] N. Front Street Sarnia, Ontario, CN N7T [illegible]
Hi Sil [illegible] Hi Sil [illegible] Hi Sil [illegible]	PPG Industries, Inc. Chemical Division One Gateway Center Pittsburgh, PA 15222
[illegible]	Rohm and Haas Company Independence Mall West Philadelphia, PA 19105
Semkit	SEMCO, A Division of Products Research & Chemical Corporation 410 Jersey Avenue Gloucester City, NJ 08030
Kraton [illegible]	Sheel Chemical Company One Shell Plaza Houston, TX 77001
Spider Brand Sulfur	Stauffer Chemical Company Nyala Farm Road Westport, CT 06880
Circo Light Oil Circosol 4240 Sundex 790 Sunpar 11	Sun Refining and Marketing Company Lubes Division 1608 Walnut Street Philadelphia, PA 19103
Te-83	Technical Processing, Inc. 106 Railroad Avenue Paterson, NJ 07509
Tullanox	Tulco, Inc. 9 Bishop Road Ayer, MA 01432

Carbowax Silane A-186 Silane A-1100 Silane A-1120	Union Carbide Corporation Silicones and Urethane Intermediates Division Old Ridgebury Road Danbury, CT 06817
E-S-E-N Flexzone 3C Rovalene 502 Sunproof Wax	Uniroyal Chemical Company Spencer Street Nagatuck, CT 06770
UOP 88	UOP Incorporated Process Division 20 UOP Plaza Mt. Prospect & Algonquin Roads Des Plaines, IL 60016
Isonol 100	Upjohn Company Polymer Chemicals Division Battleground Road P.O. Box 685 LaPorte, TX 77571
AgeRite Hipar S AgeRite Resin D AgeRite Stalite AgeRite White Altax Cumate Ethyl Tuads Methyl Tuads	R.T. Vanderbilt Company, Inc. 30 Winfield Street Norwalk, CT 06855
Sunolite 666	Witco Chemical Corporation Organics Division 277 Park Avenue New York, NY 10017

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